A LABORATORY STUDY OF BITUMINOUS MIXES USING A NATURAL FIBRE

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A LABORATORY STUDY OF BITUMINOUS MIXES USING A NATURAL FIBRE

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By
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Under the guidance of
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ROURKELA

Certificate

This is to certify that the Project Report entitled "**A LABORATORY STUDY OF BITUMINOUS MIXES USING A NATURAL FIBRE**" submitted by **Mr.DEBASHISH KAR** in partial fulfilment of the requirements for the award of Master of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this Project Report has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Generally a bituminous mixture is a mixture of coarse aggregate, fine aggregate, filler and binder. A Hot Mix Asphalt is a bituminous mixture where all constituents are mixed, placed and compacted at high temperature. HMA can be Dense Graded mixes (DGM) known as Bituminous Concrete (BC) or gap graded known as Stone Matrix Asphalt (SMA). SMA requires stabilizing additives composed of cellulose fibbers, mineral fibres or polymers to prevent drain down of the mix.

In the present study, an attempt has been made to study the effects of use of a naturally and locally available fibre called SISAL fibre is used as stabilizer in SMA and as an additive in BC. For preparation of the mixes aggregate gradation has been taken as per MORTH specification, binder content has been varied regularly from 4% to 7% and fibre content varied from 0% to maximum 0.5% of total mix. As a part of preliminary study, fly ash has been found to result satisfactory Marshall Properties and hence has been used for mixes in subsequent works. Using Marshall Procedure Optimum Fibre Content (OFC) for both BC and SMA mixes was found to be 0.3%. Similarly Optimum Binder Content (OBC) for BC and SMA were found to be 5% and 5.2% respectively. Then the BC and SMA mixes prepared at OBC and OFC are subjected to different performance tests like Drain down test, Static Indirect Tensile Strength Test and Static Creep Test to evaluate the effects of fibre addition on mix performance. It is concluded that addition of sisal fibre improve the mix properties like Marshall Stability, Drain down characteristics and indirect tensile strength in case of both BC and SMA mixes. Ii is observed that SMA is better than BC in respect of indirect tensile strength and creep characteristics.

Key Words: Bituminous Concrete (BC), Stone Matrix Asphalt (SMA), Sisal Fibre, Marshall Properties, Static Indirect Tensile Strength, Static Creep

CONTENTS

LIST OF FIGURES

LIST OF TABLE

CHAPTER-1

INTRODUCTION

1.1 GENERAL

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in-service highway can be achieved. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design. The present study is related to the mix design considerations.

A good design of bituminous mix is expected to result in a mix which is adequately (i) strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) environment friendly (v) economical and so on. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one. The present research work tries to identify some of the issues involved in this *art* of bituminous mix design and the direction of current research.

1.2 EVOLUATION OF MIX DESIGN

As per Das et al.(2004); During 1900's, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called *pat test* was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape, and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged. The first formal mix design method was Habbard field method, which was originally developed on sand-asphalt mixture. Mixes with large aggregates could not be handled in Hubbard field method.

This was one of the limitations of this procedure. Francis Hveem, a project engineer of California Department of Highways, developed the Hveem stabilometer. Hveem did not have any prior experience on judging the *just right* mix from its colour, and therefore decided to measure various mix parameters to find out the optimum quantity of bitumen. Hveem used the surface area calculation concept (which already existed at that time for cement concrete mix design), to estimate the quantity of bitumen required. Moisture susceptibility and sand equivalent tests were added to the Hveem test in 1946 and 1954 respectively. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpes of Engineers in 1930's and subsequently modified in 1940's and 50's.

1.3 BITUMINOUS MIX DESIGN

1.3.1 Objective of Bituminous mix design:-

Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size , typically less than 25 mm, through the fine filler that is smaller than 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical. The objective of the mix design is to produce a bituminous mix by proportioning various components so as to have-

1. Sufficient bitumen to ensure a durable pavement
2. Sufficient strength to resist shear deformation under traffic at higher temperature
3. Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic

4. Sufficient workability to permit easy placement without segregation

5. Sufficient resistance to avoid premature cracking due to repeated bending by traffic

6. Sufficient resistance at low temperature to prevent shrinkage cracks

1.3.2 Requirements of Bituminous mixes:-

1.3.2.1 Stability

Stability is defined as the resistance of the paving mix to deformation under traffic load. Two examples of failure are (i) shoving - a transverse rigid deformation which occurs at areas subject to severe acceleration and (ii) grooving - longitudinal ridging due to channelization of traffic. Stability depend on the inter-particle friction, primarily of the aggregates and the cohesion offered by the bitumen. Sufficient binder must be available to coat all the particles at the same time should offer enough liquid friction. However, the stability decreases when the binder content is high and when the particles are kept apart.

1.3.2.2 Durability

Durability is defined as the resistance of the mix against weathering and abrasive actions. Weathering causes hardening due to loss of volatiles in the bitumen. Abrasion is due to wheel loads which causes tensile strains. Typical examples of failure are (i) pot-holes, - deterioration of pavements locally and (ii) stripping, lost of binder from the aggregates and aggregates are exposed. Disintegration is minimized by high binder content since they cause the mix to be air and waterproof and the bitumen film is more resistant to hardening.

1.3.2.3 Flexibility

Flexibility is a measure of the level of bending strength needed to counteract traffic load and prevent cracking of surface. Fracture is the cracks formed on the surface (hairline-cracks, alligator cracks), main reasons are shrinkage and brittleness of the binder. Shrinkage cracks are due to volume change in the binder due to aging. Brittleness is due to repeated bending of the surface due to traffic loads. Higher bitumen content will give better exibility and less fracture.

1.3.2.4 Skid resistance

It is the resistance of the finished pavement against skidding which depends on the surface texture and bitumen content. It is an important factor in high speed traffic. Normally, an open graded coarse surface texture is desirable.

1.3.2.5 Workability

Workability is the ease with which the mix can be laid and compacted, and formed to the required condition and shape. This depends on the gradation of aggregates, their shape and texture, bitumen content and its type. Angular, flaky, and elongated aggregates workability. On the other hand, rounded aggregates improve workability.

1.3.2.6 Desirable properties

From the above discussion, the desirable properties of a bituminous mix can be summarized as follows:

- Stability to meet traffic demand
- Bitumen content to ensure proper binding and water proofing
- Voids to accommodate compaction due to traffic
- Flexibility to meet traffic loads, esp. in cold season
- Sufficient workability for construction
- Economical mix

1.3.3 Constituents of a mix

- Coarse aggregates: offer compressive and shear strength and shows good interlocking properties. E.g. Granite
- Fine aggregates: Fills the voids in the coarse aggregate and stiffens the binder. E.g. Sand, Rock dust
- Filler: Fills the voids, stiffens the binder and offers permeability. E.g. Rock dust, cement, lime, flyash
- Binder: Fills the voids, cause particle adhesion and gluing and offers impermeability. E.g. Bitumen, Asphalt, Tar

1.4 SELECTION OF BINDER

Different type of binder like convectional 60/70 or 80/100 penetration grade bitumen and many modified binder like Polymer Modified Bitumen (PMB), Crumb Rubber Modified Bitumen (CRMB), Natural Rubber Modified Bitumen (NRMB) is used by different researcher for their research work . Some researcher also used super pave performance grade binder like PG 76-22 with bituminous mixture like Bituminous Concrete (BC) and Stone Matrix Asphalt (SMA).

Here in this research a comparative study is done between BC and SMA with and without using fibre where 60/70 penetration grade bitumen is used as binder.

1.5 SELECTION OF STABILIZING ADDITIVE

Different stabilizing additive like fibre such as cellulose fibre, mineral fibre etc., many polymer, plastic, waste material such as carpet fibre, tires, polyester fibre are added to bituminous mix mainly with Stone Matrix Asphalt to prevent excessive draindown of binder. Natural fibre like jute fibre and coconut fibre are also used by many researchers.

Here an attempt has been made in this research work to utilise a naturally available fibre called SISAL FIBRE in bituminous mixture both in Bituminous Concrete (BC) as well as Stone Matrix Asphalt (SMA).

1.6 OBJECTIVE OF PRESENT INVESTIGATION:-

A comparative study has been made in this investigation between Bituminous Concrete (BC) and Stone Matrix Asphalt (SMA) mixes with varying binder contents (4% - 7%) and Fibre contents (0.3% - 0.5%). In the present study 60/70 penetration grade bitumen is used as binder and Sisal fibre is used as stabilizing additive.

The whole work is carried out in four different stages which is explained below.

- Study of Marshall Properties of BC mixes using three different types of fillers without fibre(fly-ash, cement, stone dust)
- Study of BC mixes with fly ash as filler and sisal fibre as stabilizer
- Study of SMA mixes with fly ash as filler and sisal fibre as stabilizer
- Evaluation of SMA and BC mixes using different test like Drain down test, Static Indirect tensile Strength test, Static Creep test

1.7 Organization of Thesis

The whole thesis is divided in to five chapters namely, introduction, review of literature, Experimental investigations, analysis and discussion of tests results and conclusions.

- introduction
- review of literature
- experimental investigations
- analysis and discussions of test results and
- conclusions

CHAPTER-2 REVIEW OF LITERATURE

2.1 GENERAL

Pavement consists of more than one layer of different material supported by a layer called sub grade. Generally pavement is two type flexible pavement and Rigid pavement. Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out then passes on these loads to the next layer below. Typical flexible pavement structure consisting of:

- *Surface course*. This is the top layer and the layer that comes in contact with traffic. It may be composed of one or several different HMA sub layers. HMA is a mixture of coarse and fine aggregates and asphalt binder
- *Base course*. This is the layer directly below the HMA layer and generally consists of aggregate (either stabilized or un-stabilized).
- *Sub-base course*. This is the layer (or layers) under the base layer. A sub-base is not always needed.

2.2 ASPHALT CONCRETE OR (BITUMINIOUS MIXTURE)

Asphalt concrete is a composite material commonly used in construction projects such as road surfaces, airports and parking lots. It consists of asphalt (used as a binder) and mineral aggregate mixed together, then are laid down in layers and compacted. Mixing of asphalt and aggregate is accomplished in one of several ways:

2.2.1 Hot mix asphalt concrete (commonly abbreviated as HMAC or HMA) is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300 °F (roughly 150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt, and the asphalt cement at 200 °F (95 °C). Paving and compaction must be performed while the asphalt is sufficiently hot. In many countries paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is packed to the optimal air content. HMAC is the form of asphalt concrete most commonly used on highly trafficked pavements such as those on major highways, racetracks and airfields.

2.2.2 Warm mix asphalt Concrete (commonly abbreviated as WMA) is produced by adding either zeo-lites waxes, asphalt emulsions, or sometimes even water to the asphalt binder prior to mixing. This allows significantly lower mixing and laying temperatures and results in lower consumption of fossil fuels, thus releasing less carbon dioxide, aerosols and vapors. Not only are working conditions improved, but the lower laying-temperature also leads to more rapid availability of the surface for use, which is important for construction sites with critical time schedules. The usage of these additives in hot mixed asphalt (above) may afford easier compaction and allow cold weather paving or longer hauls.

2.2.3 Cold mix asphalt concrete is produced by emulsifying the asphalt in water with (essentially) soap prior to mixing with the aggregate. While in its emulsified state the asphalt is less viscous and the mixture is easy to work and compact. The emulsion will break after enough water evaporates and the cold mix will, ideally, take on the properties of cold HMAC. Cold mix is commonly used as a patching material and on lesser trafficked service roads.

2.2.4 Cut-back asphalt concrete is produced by dissolving the binder in kerosene or another lighter fraction of petroleum prior to mixing with the aggregate. While in its dissolved state the asphalt is less viscous and the mix is easy to work and compact. After the mix is laid down the lighter fraction evaporates. Because of concerns with pollution from the volatile organic compounds in the lighter fraction, cut-back asphalt has been largely replaced by asphalt emulsion.

2.2.5 Mastic asphalt concrete or sheet asphalt is produced by heating hard grade blown bitumen (oxidation) in a green cooker (mixer) until it has become a viscous liquid after which the aggregate mix is then added. Then bitumen aggregate mixture is cooked (matured) for around 6-8 hours and once it is ready the mastic asphalt mixer is transported to the work site where experienced layers empty the mixer and either machine or hand lay the mastic asphalt contents on to the road. Mastic asphalt concrete is generally laid to a thickness of around $^{3}\!/_{4}$–1 $^{3}\!/_{16}$ inches (20-30 mm) for footpath and road applications and around $^{3}\!/_{8}$ of an inch (10 mm) for flooring or roof applications. In addition to the asphalt and aggregate, additives, such as polymers, and anti-stripping agents may be added to improve the properties of the final product.

2.2.6 Natural asphalt concrete can be produced from bituminous rock, found in some parts of the world, where porous sedimentary rock near the surface has been impregnated with upwelling bitumen.

2.3 HOT MIX ASPHALT

2.3.1 HMA is a mixture of coarse and fine aggregates and asphalt binder. HMA, as the name suggests, is mixed, placed and compacted at higher temperature.

HMA is typically applied in layers, with the lower layers supporting the top layer. They are Dense Graded Mixes (DGM), Stone Matrix asphalt (SMA) and various Open graded HMA. Figures below show various HMA surface and lab. Sample collected from website http://www.pavementinterective.org/article/hma-types/.

2.3.2 Dense-Graded Mixes

This type of bituminous concrete is a well-graded HMA has good proportion of all constituents are also called Dense bituminous macadam. When properly designed and constructed, a dense-graded mix is relatively impermeable. Dense-graded mixes are generally referred to by their nominal maximum aggregate size and can further be classified as either fine-graded or coarse-graded. Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes. It is Suitable for all pavement layers and for all traffic conditions. It offers good compressive strength. Materials used are Well-graded aggregate, asphalt binder (with or without modifiers)

Fig. 2.1 Dense graded HMA surface

Fig.2.2 Dense-Graded Core sample

2.3.3 Stone Matrix Asphalt (SMA)

Stone matrix asphalt (SMA), sometimes called stone mastic asphalt, is a gap-graded HMA originally developed in Europe to maximize rutting resistance and durability in heavy traffic road. SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resists permanent deformation. The stone skeleton is filled with a mastic of bitumen and filler to which fibers are added to provide adequate stability of bitumen and to prevent drainage of binder during transport and placement. Typical SMA composition consists of 70−80% coarse aggregate, 8−12% filler, 6.0−7.0% binder, and 0.3 per cent fiber. The deformation resistant capacity of SMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt (DGA) mixes. Improved binder durability is a result of higher bitumen content, a thicker bitumen film, and lower air voids content. This high bitumen content also improves flexibility. Addition of a small quantity of cellulose or mineral fiber prevents drainage of bitumen during transport and placement. There are no precise design guidelines for SMA mixes. The essential features, which are the coarse aggregate skeleton and mastic composition, and the consequent surface texture and mixture stability, are largely determined by the selection of aggregate grading and the type and proportion of filler and binder. SMA improved rut resistance and durability. It has good fatigue and tensile strength.SMA is almost exclusively used for surface courses on high volume roads. Materials used for SMA are Gap-graded aggregate, modified asphalt binder, fiber filler. Other SMA benefits include wet weather friction (due to a coarser surface texture), lower tire noise (due to a coarser surface texture) and less severe reflective cracking. Mineral fillers and additives are used to minimize asphalt binder drain-down during construction, increase the amount of asphalt binder used in the mix and to improve mix durability.

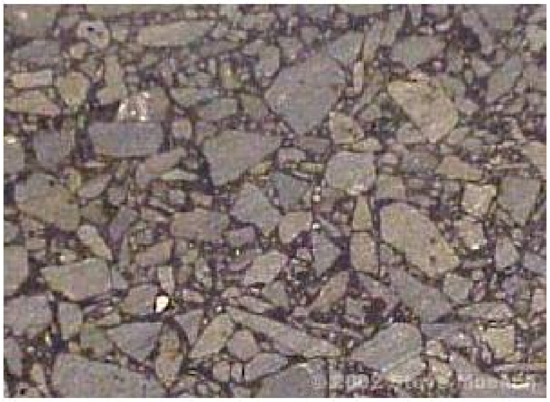

Fig.2.3 SMA Surface

Fig.2.4 SMA Lab Sample

2.3.4 Open-Graded Mixes

Unlike dense-graded mixes and SMA, an open-graded HMA mixture is designed to be water permeable. Open-graded mixes use only crushed stone (or gravel) and a small percentage of manufactured sands. The two most typical open-graded mixes are:

- Open-graded friction course (OGFC). Typically 15 percent air voids and no maximum air voids specified.
- Asphalt treated permeable bases (ATPB). Less stringent specifications than OGFC since it is used only under dense-graded HMA, SMA or Portland cement concrete for drainage.

OGFC – Used for surface courses only. They reduce tire splash/spray in wet weather and typically result in smoother surfaces than dense-graded HMA. Their high air voids reduce tire-road noise by up to 50%.

ATPB – Used as a drainage layer below dense-graded HMA, SMA or PCC.

Material used aggregate (crushed stone or gravel and manufactured sands), asphalt binder (with modifiers). OGFC is more expensive per ton than dense-graded HMA, but the unit weight of the mix when in-place is lower, which partially offsets the higher per-ton cost. The open gradation creates pores in the mix, which are essential to the mix's proper function. Anything that tends to clog these pores, such as low-speed traffic, excessive dirt on the roadway can degrade performance.

Fig.2.5 OGFC Surface

Fig 2.6 OGFC Lab Samples

2.4 PROPERTIES OF HOT MIX ASPHALT (HMA)

The bituminous mixture should posses following properties

- Resistance to Permanent Deformation
- Resistance to Fatigue and Reflective Cracking
- Resistance to Low Temperature (Thermal) Cracking
- Durability.
- Resistance to Moisture Damage (Stripping)
- Workability.
- Skid Resistance

Table 2.1 Main differences of SMA and bituminous mix (Bose et al., 2006)

Properties	SMA	BC
Definition	SMA is a gap graded mix which consists of high amount of coarse aggregate firmly bonded together by a strong asphalt matrix Consisting of fine aggregate, filler, bitumen and stabilizing additives.	.BC consists of well graded coarse and fine aggregate, filler and bitumen.
Sample fig.		
Mass of Coarse Aggregate Content, (%)	75 – 80	50-60
Mass of Fine Aggregate (%)	20 – 25	40 - 50
Mass of Filler content,(%)	9 – 13	6 – 10
Binder Type	60/70, PMB- 40	60/70, 80/100 and modified binders
Minimum binder content by weight of mix, (%)	>6.5	5 - 6
Stabilizing Additives by weight of mix,(%)	0.3 – 0.5	--------
Air Voids(%)	3—4	3--6
Layer Thickness, mm	25-75	30-65

2.5 CHARACTERISTICS OF MATERIAL USED IN BITUMINOUS MIX

2.5.1 Mineral Aggregate:-

There are various types of mineral aggregates which can be used in bituminous mixes. The aggregates used to manufacture bituminous mixes can be obtained from different natural sources such as glacial deposits or mines. These are termed as natural aggregates and can be used with or without further processing. The aggregates can be further processed and finished to achieve good performance characteristics. Industrial by products such as steel slag, blast furnace slag etc. sometimes used as a component along with other aggregates to enhance the performance characteristics of the mix. Reclaimed bituminous pavement is also an important source of aggregate for bituminous mixes.

Aggregates play a very important role in providing strength to asphalt mixtures as they Contribute a greater part in the matrix. SMA contains 70-80 percent coarse aggregate of the total Stone content. The higher proportion of the coarse aggregate in the mixture forms a skeleton-type structure providing a better stone-on-stone contact between the coarse aggregate particles resulting in good shear strength and high resistance to rutting as compare to BC. According to WSDOT (2000) the Federal Highway Administration, McLean Virginia, has suggested the following characteristics for aggregates used in bituminous mixture. The aggregates must possess -

- A highly cubic shape and rough texture to resist rutting and movements,
- A hardness which can resist fracturing under heavy traffic loads,
- A high resistance to polishing, and
- A high resistance to abrasion.

2.5.2 Mineral filler

Mineral fillers have a significant impact on the properties of SMA mixtures. Mineral fillers increase the stiffness of the asphalt mortar matrix. Mineral fillers also affect workability, moisture resistance, and aging characteristics of HMA mixtures. Generally filler plays an important role in properties of bituminous mixture particularly in terms of air voids, voids in mineral aggregate. Different types of mineral fillers are used in the SMA mixes such as stone dust, ordinary Portland cement (OPC), slag cement, fly Ash, hydrated lime etc.

Mogawer and Stuart (1996) studied the effect of mineral fillers on properties of SMA mixtures. They chose eight mineral fillers on the basis of their performance, gradation etc. They evaluated the properties of SMA mixtures in terms of drain down of the mastic, rutting, low temperature cracking, workability, and moisture susceptibility.

Mustafa Karasahin et al. (2006) used waste marble dust obtained from shaping process of marble blocks and lime stone as filler and optimum binder content was determined by Marshall Test and showed good result.

Yongjie Xue et al. (2008) utilized municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler in stone matrix asphalt mixtures. They made a comparative study of the performance of the design mixes using Superpave and Marshall Mix design procedures.

Jony Hassan et al. (2010) studied effect of using waste glass power as mineral filler on Marshall property of SMA by comparing with SMA where lime stone, ordinary Portland cement was taken as filler with varying content (4-7%).

2.5.3 Binder

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix. The characteristics of bitumen which affects the bituminous mixture behaviour are temperature susceptibility, visco-elasticity and aging. The behaviour of bitumen depends on temperature as well as on the time of loading. It is stiffer at lower temperature and under shorter loading period. Bitumen must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature. Though at low temperature it behaves like an elastic material and at high temperatures its behaviour is like a viscous fluid.

Bitumen along with different additives (fifers, polymers etc.) are act as a stabilizer for bituminous Mix. Polymer modified bitumen can also be used as a stabilizer with or without additives in the mixture. Different types of bitumen have been used by various researchers to the mixture properties. Penetration grade bitumen such as 60/70, modified bitumen such as CRMB, PMB and Superpave performance grade bitumen are used to evaluate SMA mixtures.

Brown and Mallick (1994) used viscosity grade binder AC-20 for their research on SMA properties related to mixture design. Mogawer and Stuart (1996) also used AC-20 binder. Putman et al. (2004) used a performance grade binder PG 76-22 to study the SMA properties.
They observed that polymer modified bitumen gives better performance (in terms of deformation) than unmodified bitumen.

Sharma et al. (2004) used natural rubber powder to modify 80/100 penetration grade bitumen. They termed it as Natural Rubber Modified Bitumen (NRMB). Kamaraj et al.(2006) used 60/70 grade bitumen and SBS modified bitumen (PMB-40) in SMA for their investigation. Chiu and Lu (2007) investigated the feasibility of using Asphalt Rubber (AR) as a binder for SMA. They produced this AR by blending ground tire rubber (GTR) with AC-20 asphalt. They termed it as AR-SMA. The performance of AR-SMA was evaluated in terms of moisture susceptibility. It was found that the AR-SMA mixtures were not significantly different from the conventional SMA mixtures in terms of moisture susceptibility. It was also observed that no fibre was needed to prevent drain down when this AR is used in the mix.

It has been reported by Reddy et al. (2006) that the fatigue life, temperature susceptibility and resistance to moisture damage characteristics of the bituminous mixes can be improved by the use of CRMB as compared to other unmodified bitumen.

2.5.4 Stabilizing Additives:-

.Stabilizing additives are used in the mixture to prevent mortar draindown and to provide better binding. Fibres commonly used now-a days are polypropylene, polyester, mineral and cellulose. The main stabilizing additives used in mixes can be classified in to different groups;

- Fibres’ (Cellulose Fibres, Mineral Fibres, Chemical Fibres)
- Polymer
- Powder and flour like materials (Silicic acid, Special Filler)
- Plastics (Polymer Powders or Pellets)

Natural fiber:-Natural fiber classified into 3 category depending upon the part of plant from where it is extracted

- Stem fiber (jute, banana etc.)
- Leaf fiber (sisal, pineapple)
- Fruit fiber (cotton, coir, oil palm)

Sisal fibber (http://en.wikipedia.org/wiki/sisal) obtained from the leaves of tree “agave Sisalana” which was originated from Mexico is now cultivated in Brazil, east Africa, Haiti, India, Indonesia. Sisal Fiber is exceptionally durable with a low maintenance with minimal wear and tear and it is Recyclable. Sisal fibers are obtained from the outer leaf skin, removing the inner pulp. Fine fibers are available as plaid, herring bone and twill. Sisal fibers are Anti static, does not attract or trap dust particles and do not absorb moisture or water easily. The fine texture takes dyes easily and offers the largest range of dyed colors of all natural fibers. It exhibits good sound and impact absorbing properties. Its leaves can be treated with natural borax for fire resistance properties. Traditionally, sisal has been the leading material for agricultural twine (binder twine and baler twine) because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater.

Fig-2.7 Sisal fiber

Fig-2.8 Sisal Tree

Table 2.2 Physical Properties of sisal fiber

PROPERTY	VALUE
Density (gm/cm^3)	1.5
Elongation (%)	2.0-2.5
Tensile Strength (MPa)	511-635
Young Modulus (MPa)	9.4-2.0

Table 2.3 Chemical Properties of sisal fiber

PROPERTY	VALUE
Cellulose (%)	66-78
Hemi-cellulose (%)	10-14
Lignin (%)	10-14
Pectin (%)	10
Moisture content (%)	10-22
P^H	5.7-6.2

2.5.5 Mix Design

For preparation of mix by Marshall Method some researcher used 50 blows on either face of sample and some researcher used 75 blows for their project work. on both sided of sample.

In this investigation, SMA mixes have been prepared using normal Marshall Procedure by applying 75 blows of compaction on either face of all types of mixes.

Brown and Manglorkar (1993) has done a comparative study on SMA and DGM by using 2 type aggregate (granite and local siliceous gravel) and also used cellulose and mineral fibre in SMA and did different test like Marshall test, Drain down test , Indirect tensile strength test, resilient modulus. They found that in SMA mixture the high amount of coarse aggregate forms a skeleton type structure providing a better stone-on-stone contact between coarse aggregate particle , which offer high resistance to rutting**.**SMA has shown good resistance to plastic deformation under heavy traffic loads with high tire pressure , also show good low temperature properties. Further, SMA has a rough texture which provides good friction properties after surface film of the binder is removed by the traffic.

Brown (1994) studied on SMA using different type of filler, stabilizer and concluded that Drain down in SMA is effected by type of filler, type of stabilizer , amount of stabilizer(higher the amount of stabilizer lower the drain down).Optimum binder content of SMA mixes is greater than DGM.

Bradely et al. (2004) studied Utilization of waste fibres in stone matrix asphalt mixtures. They used carpet fibre and polyester fibres and waste tires to improve the strength and stability of mixture compared to cellulose fibre. They found waste tire and carpet fibre are effective in preventing excessive drain down of SMA mixture also found that tensile strength ratio of mixes more than 100% , it means fibre don’t weaken the mixture when expose to moisture. Addition of tire and carpet fibre increases toughness of SMA. They found no difference in permanent deformation in SMA mix containing waste fibres as compared to SMA mix containing cellulose or mineral fibre.

Kamaraj et al. (2004) carried laboratory study using natural rubber powder with 80/100 bitumen in SMA by wet process as well as dense graded bituminous mix with cellulose fibre and stone dust and lime stone as filler and found its suitability as SMA mix through various tests.

Punith et al. (2004) did a comparative study of SMA with asphalt concrete mix utilizing reclaimed polythene in the form of LDPE carry bags as stabilizing agent (3 mm size and 0.4%) .The test results indicated that the mix properties of both SMA and AC mixture are getting enhanced by the addition of reclaimed polythene as stabilizer showing better rut resistance, resistance to moisture damage, rutting, creep and aging.

Reddy et al. (2004) used Crumb Rubber (CR) OBTAINED from discarded tire with 80/100 penetration grade bitumen in SMA and concluded that it improves fatigue and permanent deformation characteristics, greater resistance to moisture damage than normal mixes.

Ibrahim M.asi(2005) performed different test like Marshall stability test, loss of Marshall stability, tensile strength, loss tensile strength, resilient modulus, fatigue life, rutting resistance were conducted on both SMA and DGM . He concluded that though DGM have high compressive strength and tensile strength; SMA have higher durability, high resilience property, high rutting resistance as compare to DGM. Hence SMA is preferable in hot climate weather.

Muniandy and Huat (2006) used Cellulose oil palm fibre (COPF) and found fibre-modified binder showed improved rheological properties when cellulose fibres were pre blended in PG64-22 binder with fibre proportions of 0.2%,0.4%,0.6%,0.8 %and 1.0% by weight of aggregates. It showed that the PG64-22 binder can be modified and raised to PG70-22 grade. The Cellulose oil palm fibre (COPF) was found to improve the fatigue performance of SMA deign mix. The fatigue life increased to a maximum at a fibre content of about 0.6%, while the tensile stress and stiffness also showed a similar trend in performance. The initial strains of the mix were lowest at a fibre content of 0.6%.

Kumar et al.(2007) studied on 2 type of fibre. Tried to use a fibre in SMA by taking jute fibre which is coated with low viscosity binder and compare the result with a imported cellulose fibre (a cellulose fibre imported from Germany) using 60/70 grade bitumen. and found optimum fibre percentage as 0.3% of the mixture. Jute fibre showed equivalent results to imported patented fibres as indicated by Marshall Stability Test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fibre showed better result than patented fibre.

Mustafa and Serdal (2007) used waste marble dust obtained from shaping process of marble blocks and lime stone as filler and optimum binder content was determined by Marshall test and showed good result.

Chiu and Lu (2007) used asphalt rubber (AR) produced by blending ground tire rubber (GTR) (i) 30% of a coarse GTR with a maximum size of #20 sieve and (ii) 20% of a fine with a maximum size of #30 sieve with an asphalt, as a binder for SMA and found AR-SMA mixtures were not significantly different from conventional SMA in terms of moisture susceptibility and showed better rutting resistance than that of conventional dense graded mixture.

Shaopeng Wu et al. (2007) used basic oxygen slag as aggregate with PG76-22 modified binder and lime stone as filler and chopped polyester fibre in SMA and concluded that experimental SMA is superior than convectional SMA.

Xue et al. (2008) used municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler and Basic Oxygen Furnace (BOF) Slag as part of coarse aggregate with polyester fibre of 6.35 mm in length obtained from recycled raw materials, PG76-22 binder in the SMA mix and performed Marshall and super pave method of design and found it's suitability for use in the SMA mix.

C.S Bindu , Beena K.S. (2010) used shredded waste plastic as stabilizing agent in stone matrix asphalt mixture and compare its property with SMA without stabilizing agent. Marshall Test, compressive strength test, tensile strength test, tri axial test were performed with varying percentage of bitumen (6-8%) and different percentage of plastic (6-12%) by wt. of mix.

Jony Hassanet.al.(2010) studied effect of using waste glass power as mineral filler on Marshall property of SMA by comparing with SMA where lime stone, ordinary Portland cement was taken as filler with varying content (4-7%) . Optimum glass power content was found 7%. By using glass power as filler in SMA its stability increases up to 13%, flow value decreases up to 39%, density also decreases as compare to SMA contains lime stone and cement filler.

2.6 Concluding Remarks

The review of literature gives an overview of the researches were done on bituminous mixture like stone matrix asphalt (SMA) and Dense graded mixtures. Keeping the important points of the researches in mind, the materials of SMA and Bituminous concrete (BC) with its composition and the corresponding test methods for the present investigation have been chosen. Here an attempt has been made to compare the different properties of SMA and BC through different test like Marshall Test, Indirect Tensile stress Test, Static Creep Test where 60/70 penetration grade bitumen is taken as binder and fly ash as filler. . In this research work the MORTH gradation has been adopted. . Investigators mainly have focused on uses of cellulose fiber and other materials in the mixes to prevent drain down of binder mortar from the mix. Use of a non conventional fiber such as SISAL fiber which primarily contain cellulose on its outer part and is widely and cheaply available all over the world, is not available in past literature, particularly in SMA mixes. Hence this material has been used as the stabilizing additive in the preparation of BC and SMA mixes. This would solve to good extent the problem of solid waste management and at the same time explore the possibility of using a non conventional waste material in a typically non conventional mix like SMA.

CHAPTER – 3 EXPERIMENTAL INVESTIGATIONS

3.1 Introduction

This chapter describes the experimental works carried out in this present investigation. This chapter is divided into two parts. First part deals with the experiments carried out on the materials (aggregates, filler, bitumen, and fibre), second part deals with the tests carried out on bituminous mixes.

3.2 Tests on Materials Used

3.2.1 Aggregates

For preparation of Bituminous mixes (BC, SMA) aggregates as per MORTH grading as given in Table 3.1 and Table 3.2 respectively, a particular type of binder and fibre in required quantities were mixes as per Marshall Procedure.

Table 3.1 Adopted aggregate Gradation for BC (MORTH)

Sieve size (mm)	Percentage passing
26.5	100
19	95
9.5	70
4.75	50
2.36	35
0.30	12
0.075	5

Table 3.2 Adopted aggregate Gradation for SMA (MORTH)

Sieve size (mm)	Percentage passing
16	100
13.2	94
9.5	62
4.75	34
2.36	24
1.18	21
0.6	18
0.3	16
0.15	12
0.075	10

3.2.1.1 Coarse Aggregates

Coarse aggregates consisted of stone chips collected from a local source, up to 4.75 mm IS sieve size. Its specific gravity was found as **2.75**. Standard tests were conducted to determine their physical properties as summarized in Table 3.3

3.2.1.2 Fine Aggregates

Fine aggregates, consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Its specific gravity was found as **2.6.**

3.2.2 Filler

Aggregate passing through 0.075 mm IS sieve is called as filler. Here cement, fly ash and Stone dust are used as filler whose specific gravity are 3.0, 2.2, 2.7 respectively.

First a comparative study is done on BC where all these three types of fillers is used but later on only fly ash is used as filler where a comparative study is done on BC as well as SMA with or without using fibre.

Table 3.3 Physical Properties of Coarse aggregate

Property	Test Method	Test Result
Aggregate Impact Value (%)	IS: 2386 (P IV)	14.3
Aggregate Crushing Value (%)	IS: 2386 (P IV)	13.02
Los Angels Abrasion Value (%)	IS: 2386 (P IV)	18
Flakiness Index (%)	IS: 2386 (P I)	18.83
Elongation Index (%)	IS: 2386 (P I)	21.5
Water Absorption (%)	IS: 2386 (P III)	0.1

3.2.3 Binder

Here 60/70 penetration grade bitumen is used as binder for preparation of Mix, whose specific gravity was 1.01. It's important property is given in table 3.4

Table 3.4 Properties of Binder

Property	Test Method	Value
Penetration at 25°C (mm)	IS : 1203-1978	67.7
Softening Point (°C)	IS : 1203-1978	48.5
Specific gravity	IS : 1203-1978	1.03

3.2.4 Fibre

Here sisal fibre is used as additive whose length is about 900 mm. and diameter varied from 0.2 to 0.6 mm. The sisal fibres were cleaned and cut in to small pieces of 15-25 mm in length to ensure proper mixing with the aggregates and binder during the process of mixing.

3.3 Preparation of Mixes

The mixes were prepared according to the Marshall procedure specified in ASTM D1559. For BC and SMA the coarse aggregates, fine aggregates and filler were mixed according to the adopted gradation as given in Table 3.1. and Table 3.2 respectively. First a comparative study is done on BC by taking three different type of filler i.e. cement, fly ash, stone dust. Here Optimum Binder Content (OBC) was found by Marshall Test where binder content is very from 0% to 7%. Then Optimum Binder Content (OBC) and Optimum fibre Content (OFC) of both BC and SMA was found by Marshall Method where binder content is very from 0% to 7% and fibre content is vary from 0.3% to 0.5%. The sisal fibres after being cut in to small pieces (15-20 mm) were added directly to the aggregate sample in different proportions. The mineral aggregates with fibres and binders were heated separately to the prescribed mixing temperature. The temperature of the mineral aggregates was maintained at a temperature 10°C higher than the temperature of the binder. Required quantity of binder was added to the pre heated aggregate-fibre mixture and thorough mixing was done manually till the colour and consistency of the mixture appeared to be uniform. The mixing time was maintained within 2-5 minutes. The mixture was then poured in to pre-heated Marshall Moulds and the samples were prepared using a compactive effort of 75 blows on each side. The specimens were kept overnight for cooling to room temperature. Then the samples were extracted and tested at 60°C according to the standard testing procedure.

3.4 Tests on Mixes

Presented below are the different tests conducted on the bituminous mixes with variations of binder type and quantity, and fibre concentration in the mix.

3.4.1 Marshall Test

Marshall Mix design is a standard laboratory method, which is adopted worldwide for determining and reporting the strength and flow characteristics of bituminous paving mixes. In India, it is a very popular method of characterization of bituminous mixes. This test has also been used by many researchers to test bituminous mixes. This test method is widely accepted because of its simplicity and low of cost. Considering various advantages of the Marshall method it was decided to use this method to determine the Optimum Binder Content (OBC) of the mixes and also study various Marshall Characteristics such as Marshall Stability, flow value, unit weight, air voids etc.

Figures 3.1 and 3.2 show the Marshall sample and Marshall Apparatus with a loaded Marshall specimen. The Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder contents (OBC) and optimum fibre contents (OFC). The mix volumetric of the Marshall samples such as unit weight, air voids were calculated by using the procedure reported by Das and Chakroborty (2003). For constraint of time each and every test on all types of mixes cannot be completed. Hence it was decided to carry out the next set of experiments such as drain down test, static indirect tensile test and moisture susceptibility tests on the mixes prepared at their OBC and OFC.

Fig 3.1 Marshall Sample

Fig 3.2 Marshall Test In Progress

3.4.2 Drain down test

There are several methods to evaluate the drain-down characteristics of bituminous mixtures. The drain down method suggested by MORTH (2001) was adopted in this study. The drainage baskets fabricated locally according to the specifications given by MORTH (2001) is shown in Figure 3.3. The loose un-compacted mixes were then transferred to the drainage baskets and kept in a pre-heated oven maintained at 150°C for three hours. Pre-weighed plates were kept below the drainage baskets to collect the drained out binder drippings. From the drain down test the binder drainage has been calculated from the equation :-

Drain down equation is

$$d = \frac{W_2 - W_1}{1200 + X}$$

Where

W_1 = initial mass of the plate

W_2 = final mass of the plate and drained binder

X = initial mass of fibres in the mix

For a particular binder three mixes were prepared at its optimum binder content and the drain down was reported as an average of the three. Figure 3.3 shows the drainage of 60/70 bitumen.

Fig 3.3 Drainage of 60/70 bitumen sample (SMA without fibre)

3.4.3 Indirect Tensile Strength Test

Indirect tensile test is used to determine the indirect tensile strength (ITS) of bituminous mixes. In this test, a compressive load is applied on a cylindrical specimen (Marshall Sample) along a vertical diametrical plane through two curved strips the radius of curvature of which is same as that of the specimen. A uniform tensile stress is developed perpendicular to the direction of applied load and along the same vertical plane causing the specimen to fail by splitting. This test is also otherwise known as splitting test. This test can be carried out both under static and dynamic (repeated) conditions. The static test provides information about the tensile strength, modulus of elasticity and Poisson's ratio of bituminous mixes.

The static indirect tensile strength test has been used to evaluate the effect of moisture on bituminous mixtures.

3.4.3.1 Static Indirect Tensile Test

This test was conducted using the Marshall test apparatus with a deformation rate of 51 mm per minute. A compressive load was applied along the vertical diametrical plane and a proving ring was used to measure the load. A Perspex water bath (270 mm × 250 mm × 195 mm) was prepared and used to maintain constant testing temperature. Two loading strips, 13 mm (1/2″) wide, 13 mm deep and 75 mm long, made up of stainless steel were used to transfer the applied load to the specimen. The inside diameter of the strip made was same as that of a Marshall sample (102 mm**)**. Fig. 3.5 shows the static indirect tensile test being carried out on a specimen. Fig. 3.6 shows a close view of the loaded specimen. The sample was kept in the water bath maintained at the required temperature for minimum 1/2 hours before test. The Perspex water bath maintained at the same test temperature was placed on the bottom plate of the Marshall apparatus. The sample was then kept inside the Perspex water bath within the two loading strips. Loading rate of 51 mm/minute was adopted.

The load was applied and the failure load was noted from the dial gauge of the proving ring. The tensile strength of the specimen was calculated by using the formula given in ASTM D 6931 (2007) and mentioned in Equation given below:-

$$S_T = \frac{\mathbf{2000 \times P}}{\boldsymbol{\pi \times t \times d}}$$

Where

S_T == Indirect Tensile Strength, KPa

P = Maximum Load, N

t = Specimen height before testing, mm

D = Specimen Diameter, mm

The test temperature was varied from 5°C to 40°C at an increment of 5°C In this test three Marshall samples were tested at a particular temperature and the tensile strength was reported as the average of the three test results.

Fig 3.4 Static Indirect Tensile Test in progress **Fig 3.5 Close View of loaded sample**

Fig 3.6 Specimen tested at 5°C

Fig 3.7 Specimen tested at 10°C

Fig 3.8 Specimen tested at 40°C

3.4.4 Static Creep Test

For Static Creep test sample were prepared at their OBC and OFC. The test consists of two stages. In first stage a vertical load of 6 KN is applied for 30 min. The deformation was registered during these 0, 10, 20, 30 min using a dial gauge graduated in units of 0.002 mm and it was able to register a maximum deflection of 5 mm. Secondly, the load was removed and its deformation had been registered during next 10 min interval of time i.e. 40, 50, 60 min. Here throughout the test temperature is maintained 40°C. A graph has been plot between time-deformation which shown next chapter.

Fig 3.9 Static Creep Test In Progress

CHAPTER – 4 ANALYSES OF TEST RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter Result and Observation of test carried out in previous chapter is presented, analyzed and discuss. This chapter is divided into five sections. First section is deals with parameter used for analysis. Second section deals with calculation of Optimum binder Content (OBC) of BC where cement, fly ash, stone dust is used as filler. Third section deals with calculation of Optimum binder Content (OBC) and Optimum Fibre content (OFC), Marshall Properties of BC with or without using fibre. Fourth section deals with calculation of Optimum binder Content (OBC) and Optimum Fibre content (OFC), Marshall Properties of SMA with or without using fibre. Fifth section deals with result of Drain down test and Static Indirect Tensile Stress and static Creep test.

4.2 PARAMETERS USESD:-

Based on volume considered in evaluating specific gravity of an aggregate, some definitions of specific gravity are proposed. As per Das A. and Chakroborty P. (2010); the definitions and other formulae used in calculations hereafter are as follows:

4.2.1 Bulk Specific Gravity Of aggregate (G_{sb})

$$G_{sb} = \frac{M_{agg}}{volume\ of\ (agg.mass+airvoid\ in\ agg.+absorb\ bitumen)}$$

Where M_{agg} = Mass of aggregate

4.2.2 Effective specific gravity of aggregate(G_{se})

$$G_{se} = \frac{M_{agg}}{volume\ of\ (agg.mass+air\ void\ in\ aggregate)}$$

Where M_{agg} = mass of aggregate

$$G_{se} = (M_{mix} - M_b) / (\frac{M_{mix}}{G_{mm}} - \frac{M_b}{G_b})$$

Where M_b = mass of bitumen used in mix

G_b = specific gravity of bitumen

4.2.3 Apparent Specific Gravity (G_a)

$$G_a = \frac{M_{agg}}{volume\ of\ aggregate\ mass}$$

4.2.4 Theoretical Maximum Specific Gravity of Mix (G_{mm})

$$G_{mm} = \frac{M_{mix}}{volume\ of\ (mix-air\ voids)}$$

4.2.5 Bulk Specific Gravity of Mix (G_{mb})

$$G_{mb} = \frac{M_{mix}}{bulk\ volume\ of\ mix}$$

4.2.6 Air Voids (VA)

$$VA= \left[1 - \frac{G_{mb}}{G_{mm}}\right]*100$$

4.2.7 Voids In Mineral Aggregates (VMA)

$$VMA = \left[1 - \frac{G_{mb}}{G_{mm}} * P_S\right] *100$$

Where P_s = percentage of aggregate present by total mass of mix

4.2.8 Voids Filled With Bitumen (VFB)

$$VFB = \left[\frac{VMA - VA}{VMA}\right] * 100$$

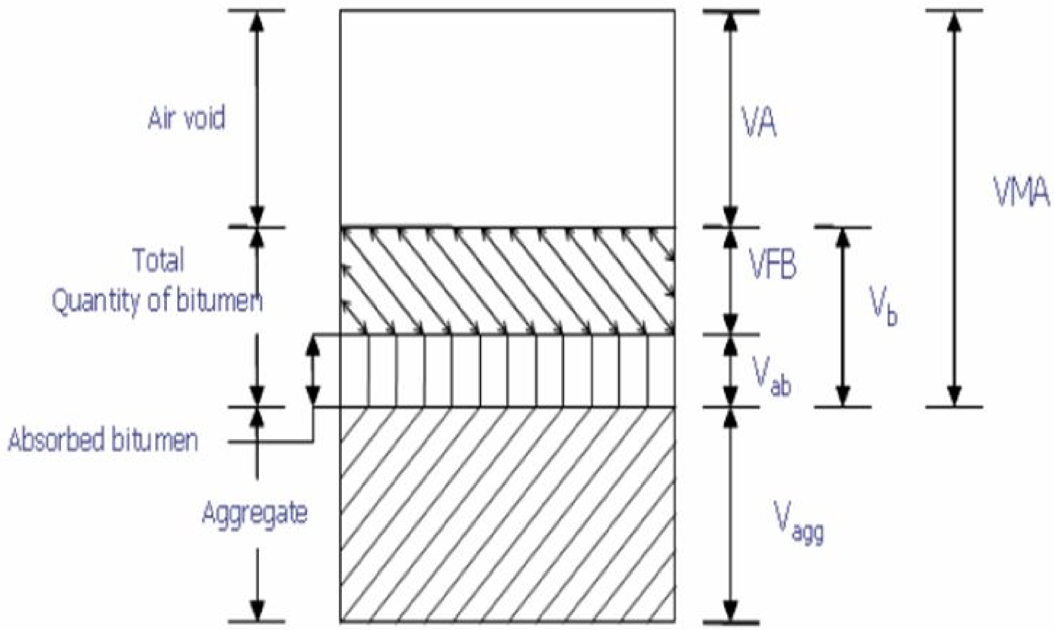

Fig 4.1 Phase Diagram of bituminous mix

4.3 EFFECT OF DIFFERENT TYPE OF FILLER ON BC:-

Variation of Marshall Properties of bituminous concrete (BC) with different type of filler is explained below.

4.3.1 Marshall Stability

It is observed that stability value increases with increase binder content up to certain binder content; then stability value decreases. Variation of Marshall Stability value with different binder content with different filler is given fig 4.1.

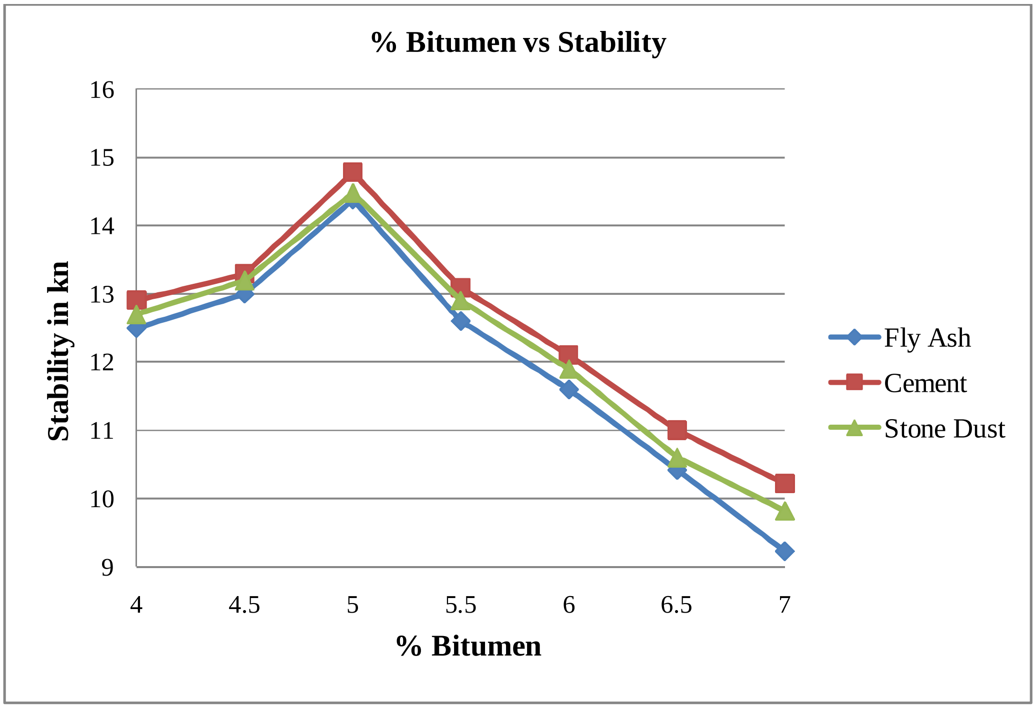

Fig 4.2 Variation of Marshall Stability of BC with different binder content

(With different type of filler)

Table 4.1 Maximum Marshall Stability values and their corresponding binder content

BC with filler type	Max. Stability (KN)	Corresponding Binder Content (%)
Cement	14.78	5
Stone dust	14.48	5
Fly ash	14.38	5

4.3.2 Flow Value

It is observed that with increase binder content flow value increases. For BC flow value should be within 2 to 4 mm. Variation of flow value with different binder content of BC with different filler is shown in fig 4.2

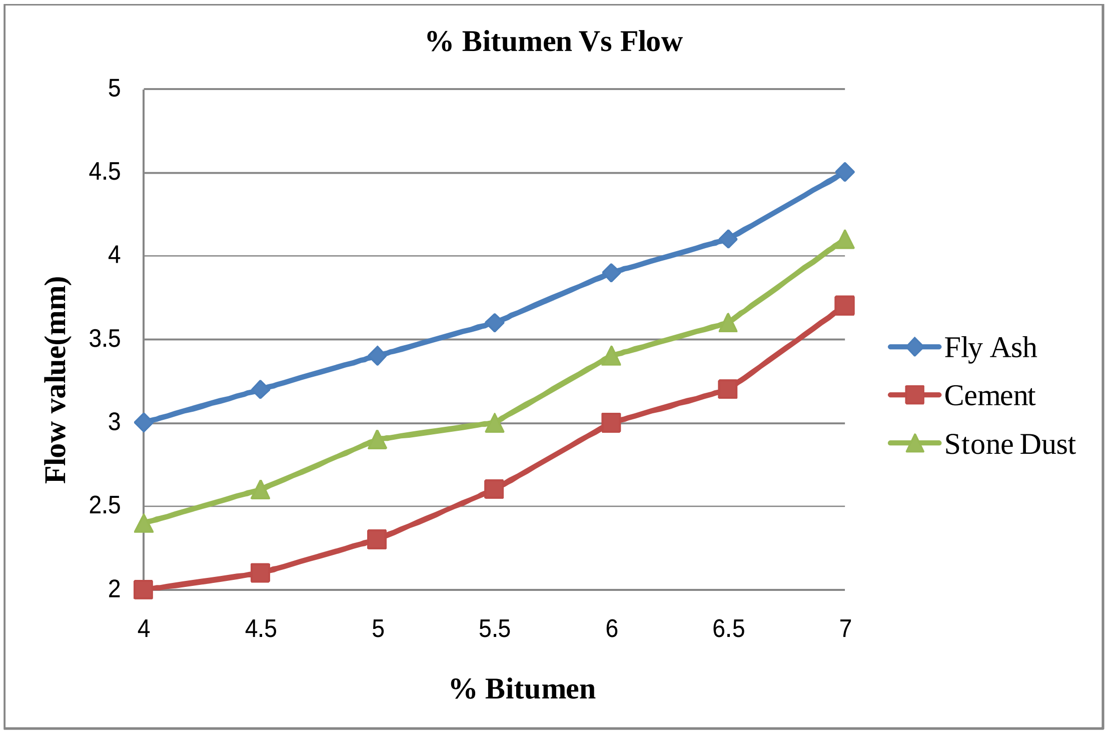

Fig 4.3 Variation of Flow Value of BC with different binder content

(With different type of filler)

4.3.3 Unit Weight

It is observed that unit weight increases with increase binder content up to certain binder content; then decreases. Variation of unit weight value with different binder content with different filler is given fig 4.3

.

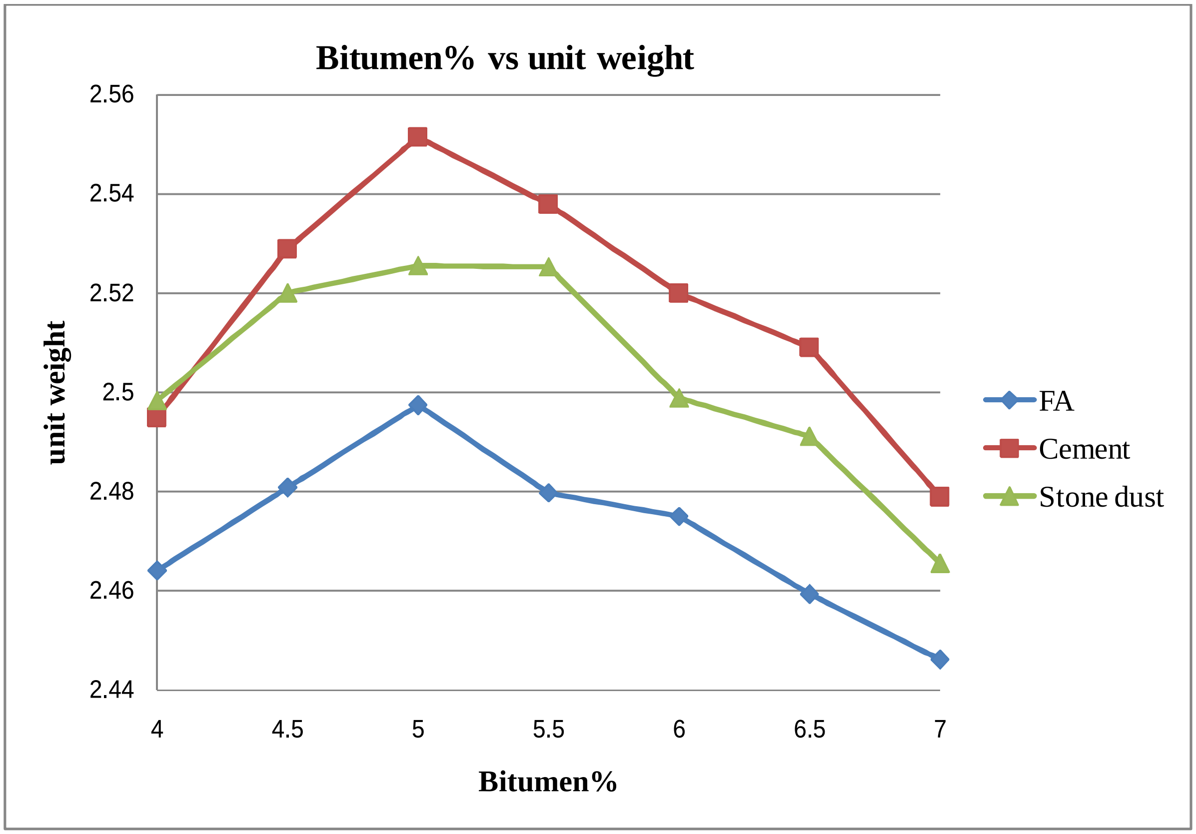

Fig 4.4 Variation of unit weight Value of BC with different binder content

(With different type of filler)

Table 4.2 Maximum unit weight values and their corresponding binder content

BC with filler type	Max. Unit weight	Corresponding Binder Content (%)
Cement	2.54	5
Stone dust	2.52	5
Fly ash	2.49	5

4.3.4 Air Void

It is observed that with increase binder content air void decreases. Variation of air void with different binder content is given fig 4.4.

MORTH recommended it should be lies between 3 to 6%. Hence the binder content at 4.5% of air void given below table 4.3.

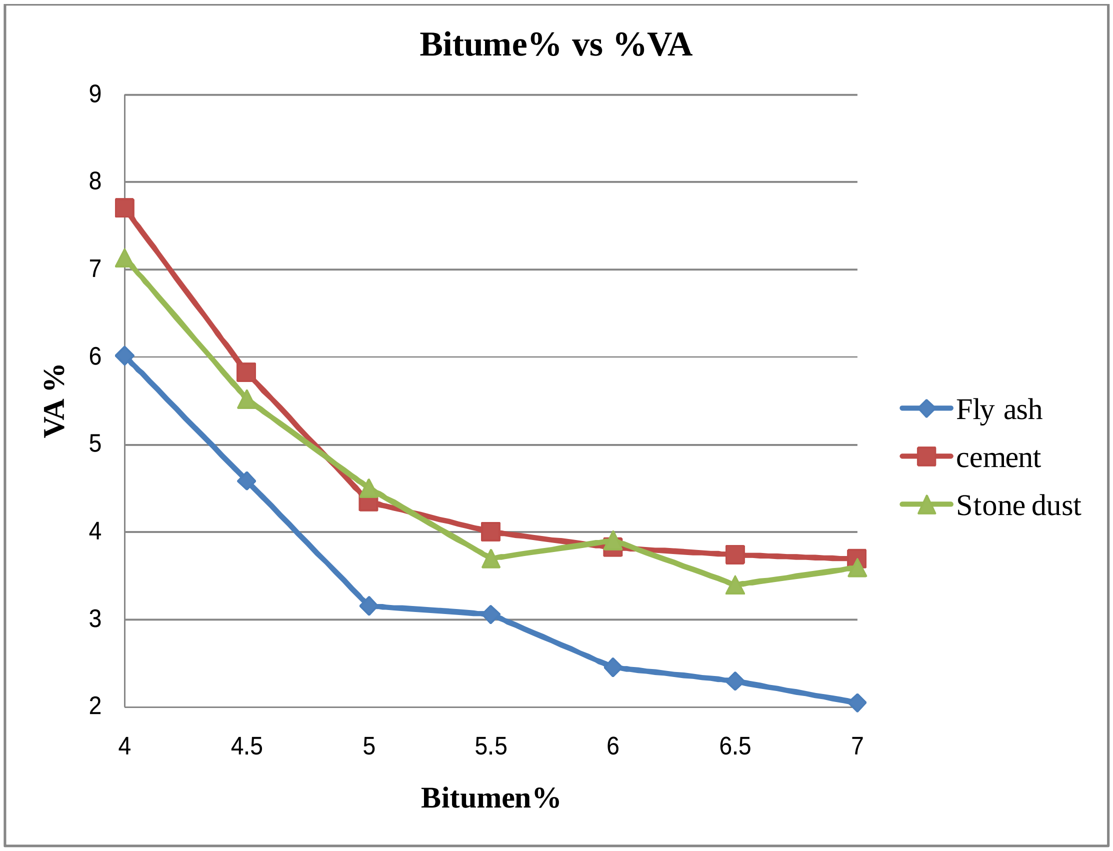

Fig 4.5 Variation of air void of BC with different binder content

(With different type of filler)

Table 4.3 binder content corresponding to 4.5% of air void

BC with filler type	Air void (%)	Corresponding Binder Content (%)
Cement	4.5	5
Stone dust	4.5	5
Fly ash	4.5	4.8

4.3.5 Voids in Mineral Aggregate (VMA)

It is observed that first it decreases and then it increases at sharp rate. Variation of VMA with different binder content is shown in Fig 4.5

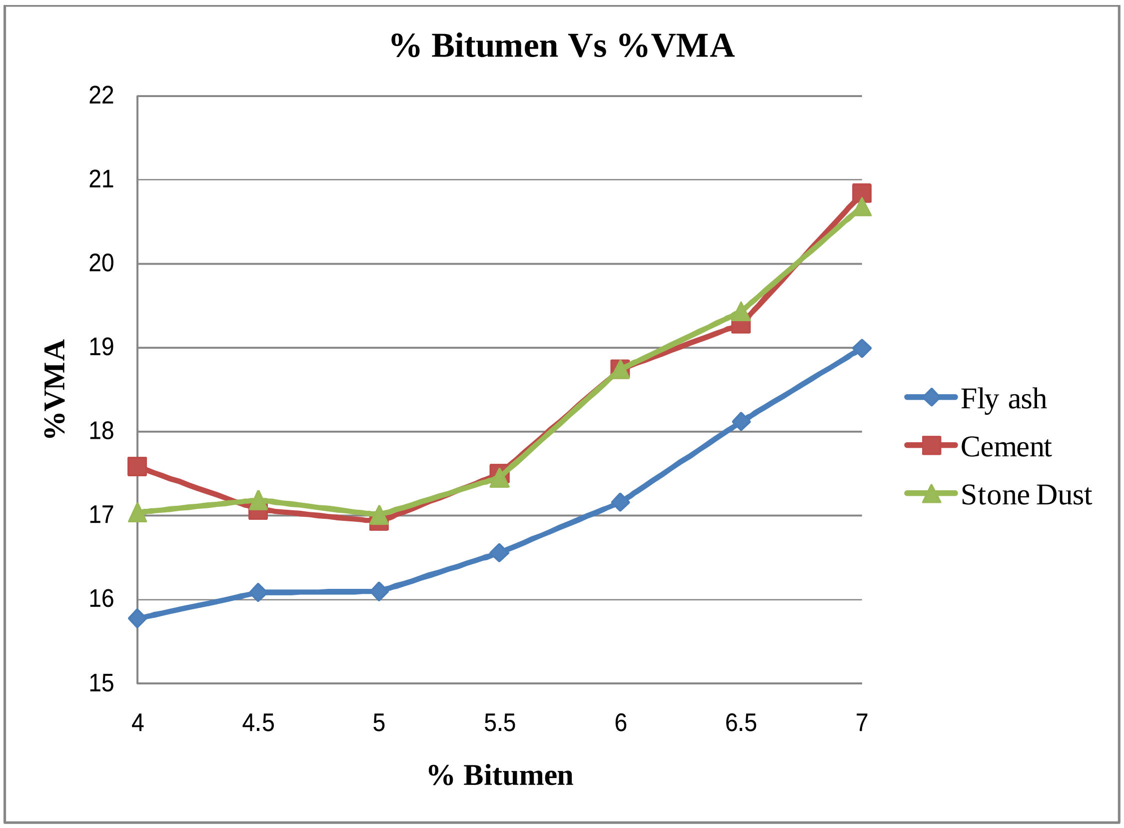

Fig 4.6 Variation of VMA of BC with different binder content

(With different type of filler)

4.3.6 Void filled with Bitumen (VFB)

VFB increases with increase binder content. Variation of VFB with different binder content is shown in Fig 4.6

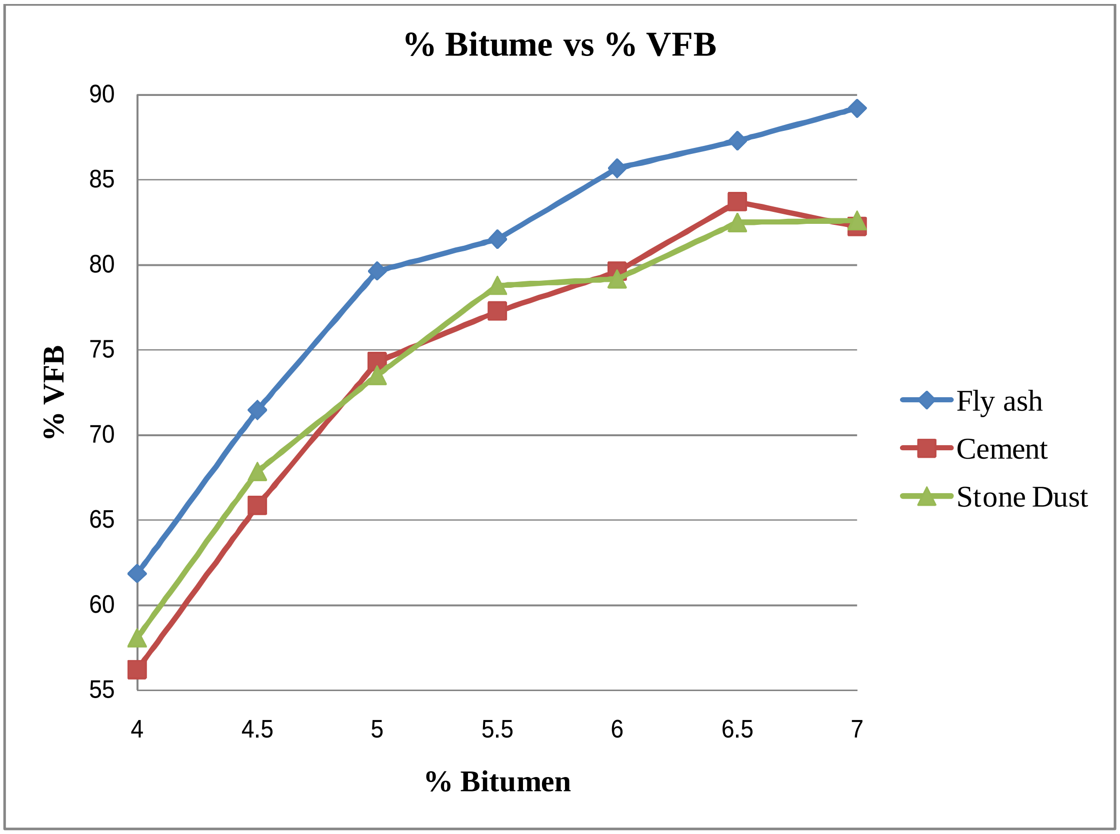

Fig 4.7 Variation of VFB of BC with different binder content

(With different type of filler)

4.3.7 OPTIMUM BINDER CONTENT

Optimum Binder Content is found out by taking average value of following three bitumen content found from above graph i.e.

I. Bitumen content correspond to maximum stability
II. Bitumen content correspond to maximum unit weight
III. Bitumen content corresponding to the median of designed limits of percentage air voids in total mix

OBC of BC with different type of filler is given table 4.4

Table 4.4 OBC of BC with different type of filler

BC With filler type	OBC (%)
Cement	5
Stone dust	5
Fly ash	4.8

From above result it has been observed that BC mixes with all three type of filler produce satisfactory result as suggested as in MORTH. Here mixes with cement filler gives higher stability and other improved characteristics followed by stone dust filler and then fly ash filler. Here fly ash has been selected as filler material for further investigation considering its wide availability, low cost price and environment protection.

4.4 EFFECT OF FIBRE ON BC:-

For preparation of mix binder content vary from 4 to 7% and fibre content vary from 0.3% to 0.5%. Here OBC, OFC and other Marshall properties is calculated by Marshall Method.

4.4.1 Marshall Stability

It is observed that stability value increases with increase binder content up to certain binder content; then stability value decreases. Also stability value increases with increase fibre content and further addition of fibre it decreases. Variation of Marshall Stability value with different binder content with different fibre is given fig 4.7.

Table 4.5 Maximum Marshall Stability values and their corresponding binder content

Fibre content (%) >	0		0.3		0.5	
BC with binder	Max. Stability (KN)	Binder Content (%)	Max. Stability (KN)	Binder Content (%)	Max. Stability (KN)	Binder Content (%)
60/70	14.38	5	14.55	5	14.1	5

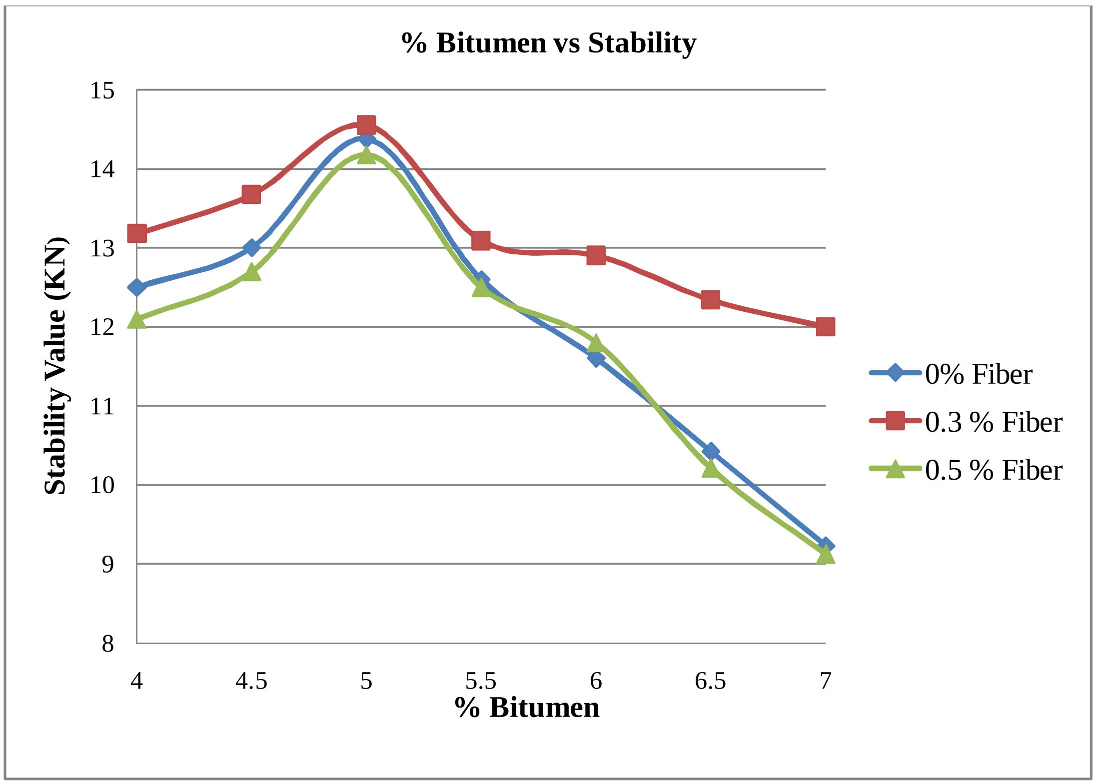

Fig 4.8 Variation of Marshall Stability of BC with different binder content

(With different fibre content)

4.4.2 Flow Value

It is observed that with increase binder content flow value increases. For BC flow value should be within 2 to 4 mm.. Variation of flow value with different binder content of BC with different fibre content is shown in fig 4.8

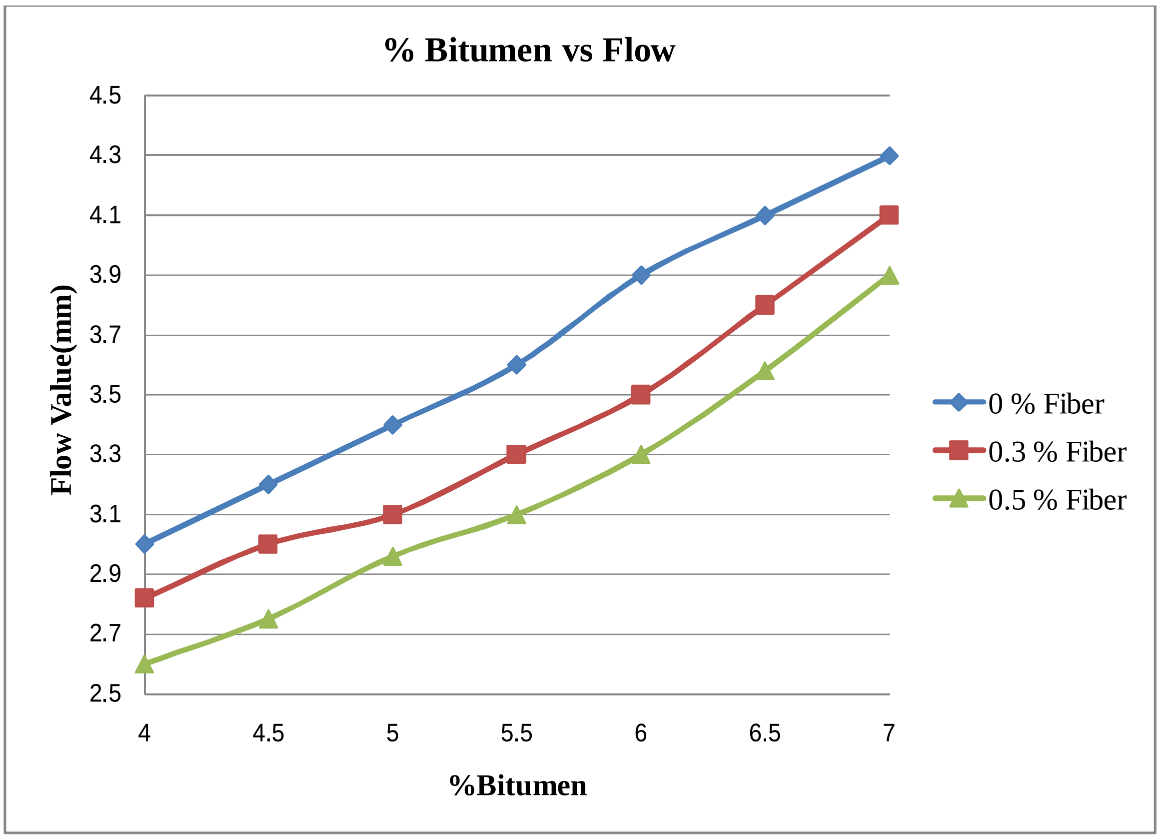

Fig 4.9 Variation of Flow value of BC with different binder content

(With different fibre content)

4.4.3 Unit weight

It is observed that unit weight increases with increase binder content up to certain binder content; then decreases. Variation of unit weight value with different binder content with different fibre is given fig 4.9

Table 4.6 Maximum unit weight values and their corresponding binder content

Fibre content (%) >	0		0.3		0.5	
BC with binder	Max. Unit wt.	Binder Content (%)	Max. Unit wt.	Binder Content (%)	Max. Unit wt.	Binder Content (%)
60/70	2.49	5	2.45	5	2.45	5

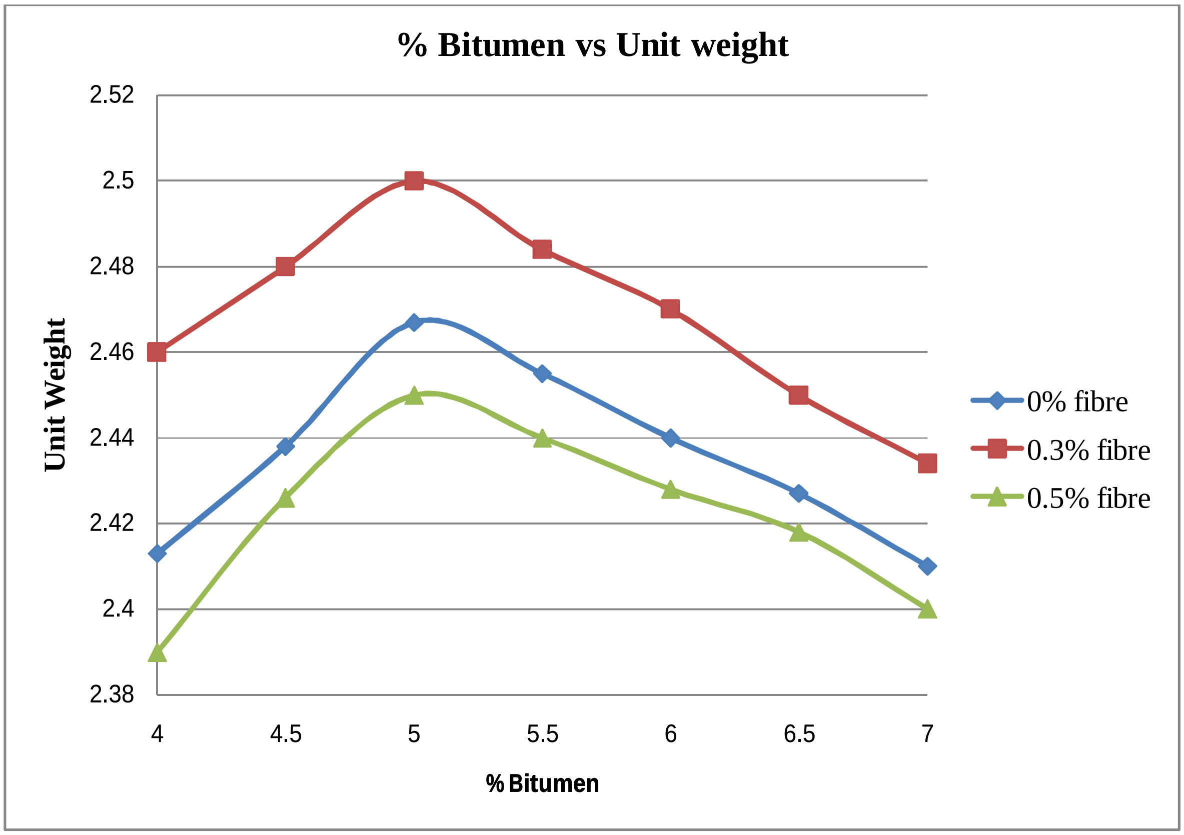

Fig 4.10 Variation of unit weight of BC with different binder content

(With different fibre content)

4.4.4 Air Void

It is observed that with increase binder content air void decreases. Variation of air void content with different fibre content is given fig 4.8. MORTH recommended it should be lies between 3 to 6%. Hence the binder content at 4.5% of air void given below table 4.7

Table 4.7 binder content corresponding to 4.5% of air void

BC with fibre content (%)	Air void (%)	Corresponding Binder Content (%)
0	4.5	5
0.3	4.5	6
0.5	4.5	6.5

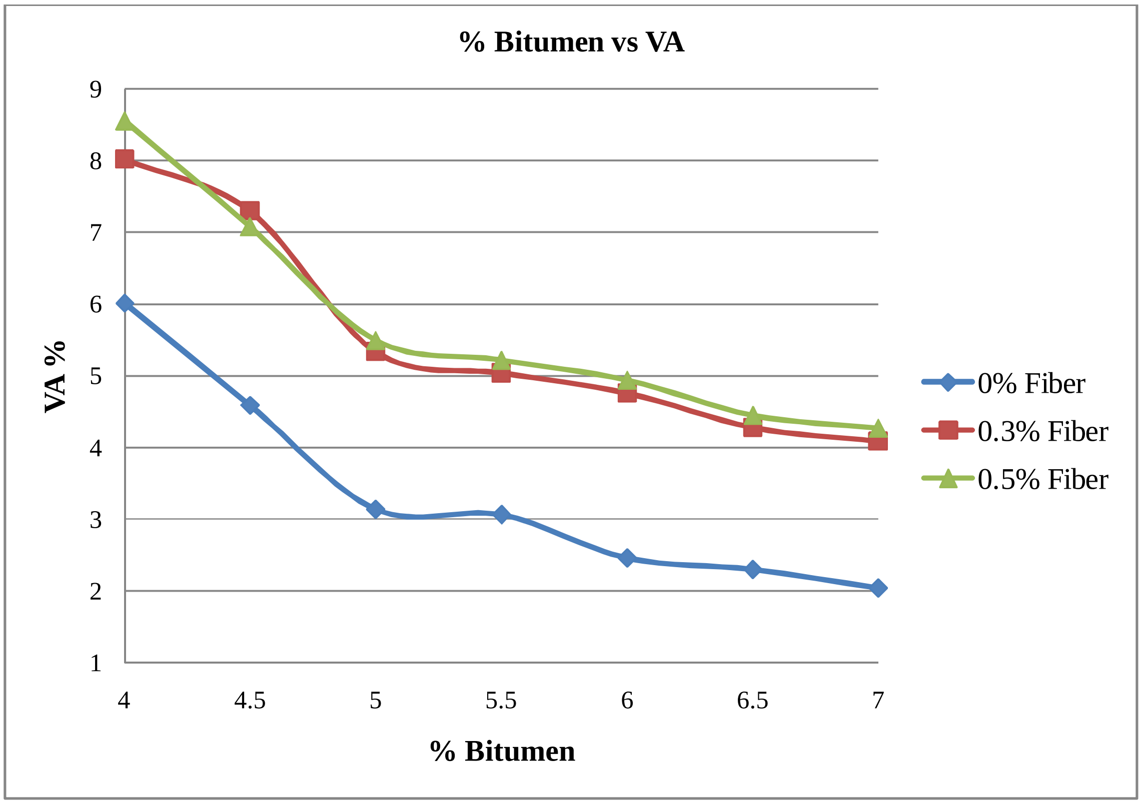

Fig 4.11 Variation of Air Void of BC with different binder content

(With different fibre content)

4.4.5 Void In Mineral Aggregate (VMA)

It is observed that first it decreases and then it increases at sharp rate. Variation of VMA with different binder content with different fibre content is shown in Fig 4.11

4.4.6 Void Filled With Bitumen (VFB)

It is observed that first it increases at sharp rate. Variation of VFB with different binder content with different fibre content is shown in Fig 4.12

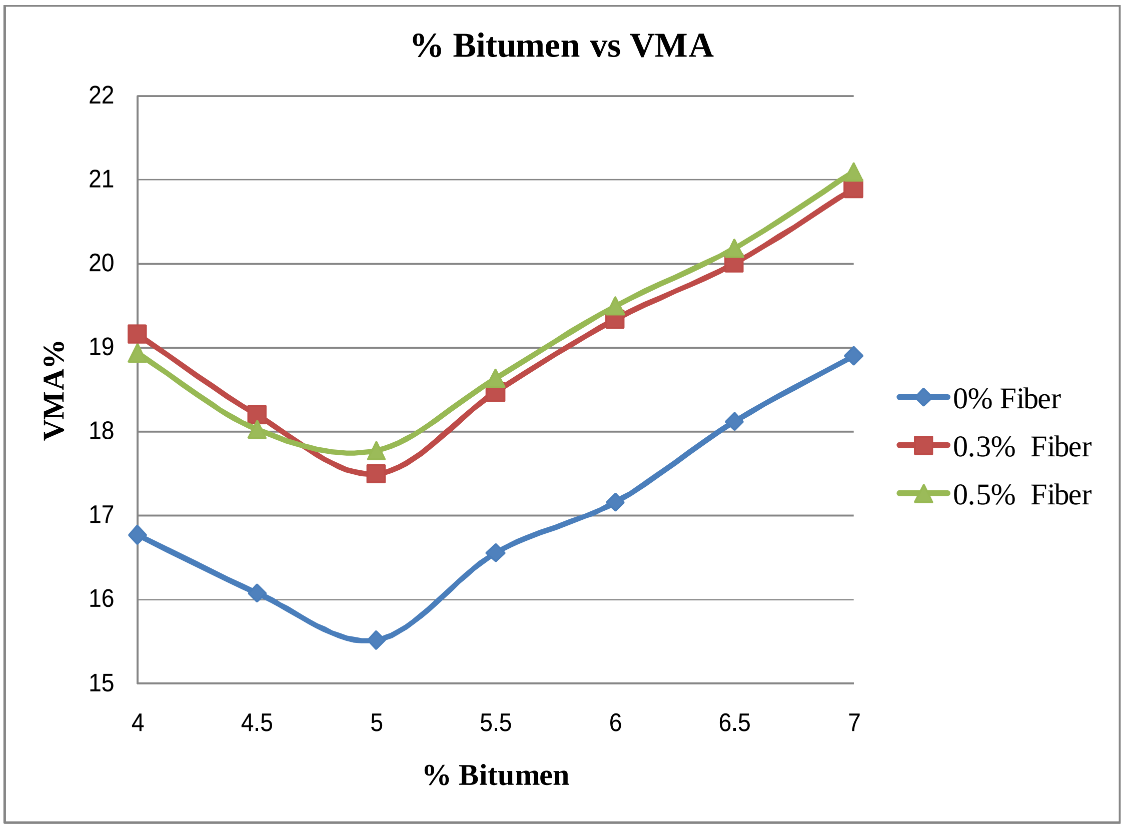

Fig 4.12 Variation of VMA of BC with different binder content

(With different fibre content)

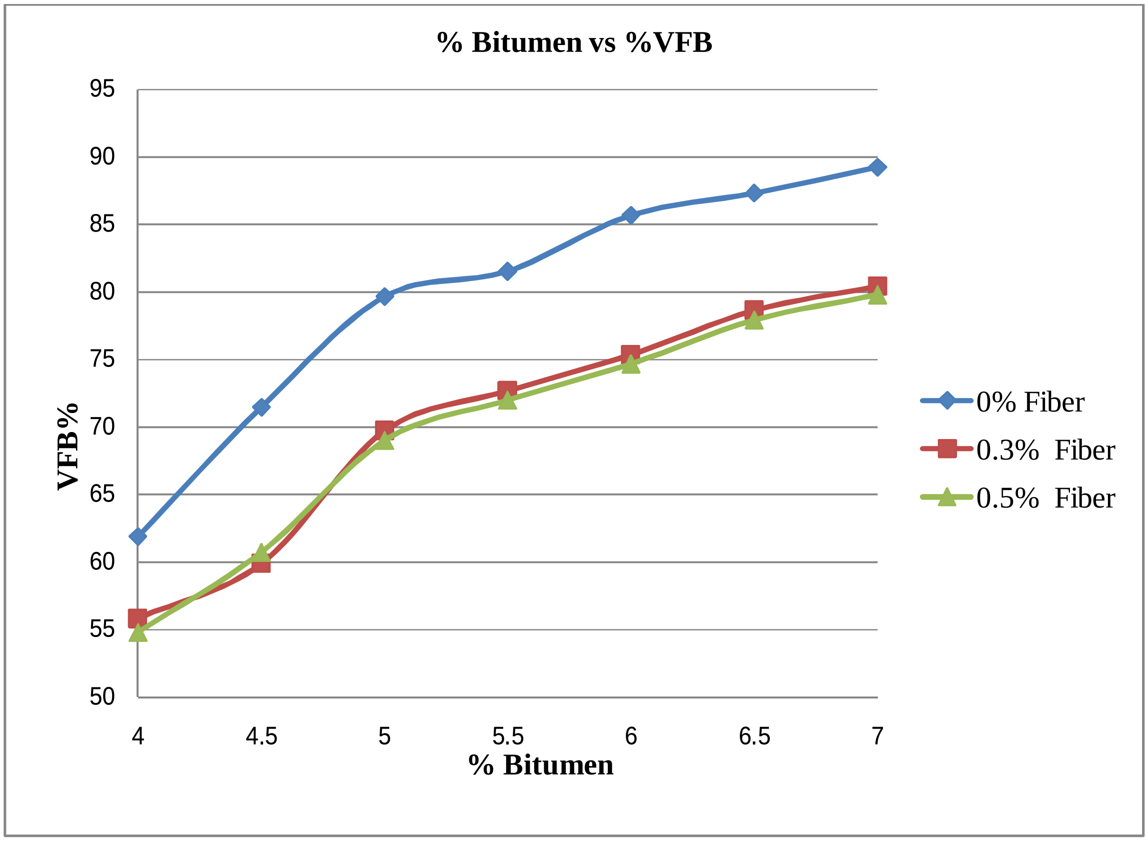

Fig 4.13 Variation of VFB of BC with different binder content

(With different fibre content)

4.4.7 OPTIMUM BINDER CONTENT

Optimum Binder Content is found out by taking average value of following three bitumen content found from above graph i.e.

I. Bitumen content correspond to maximum stability
II. Bitumen content correspond to maximum unit weight
III. Bitumen content corresponding to the median of designed limits of percentage air voids in total mix

OBC of BC with different type of filler is given table 4.8

Table 4.8 OBC of BC with different fibre content

BC With fibre content (%)	OBC (%)
0	4.8
0.3	5
0.5	5.5

As addition of 0.3% of fibre the stability value increases and flow value decreases and further addition of fibre 0.5% stability decreases and flow value increases. Hence Here for BC OBC is taken as 5% and OFC value is taken as 0.3%.

4.5 EFFECT OF FIBRE ON SMA

Here result of variation of Marshall Properties with different binder content where fibre content is taken as 0%, 0.3%, and 0.5% is explained below.

4.5.1 Marshall Stability

It can be observed that with increase binder content stability value increases up to certain binder content and there after it decreases. Similarly by addition of fibre stability value also increases up to certain limits and further addition of fibre stability value starts decreasing. May be this is due to excess amount of fibre which is not able to mix in asphalt matrix properly. The result is given below in fig 4.13

Table 4.9 Maximum Marshall Stability values and their corresponding binder content

Fibre content (%) >	0		0.3		0.4	
SMA with binder	Max. Stability (KN)	Binder Content (%)	Max. Stability (KN)	Binder Content (%)	Max. Stability (KN)	Binder Content (%)
60/70	12.3	6	14.5	5.5	14	6

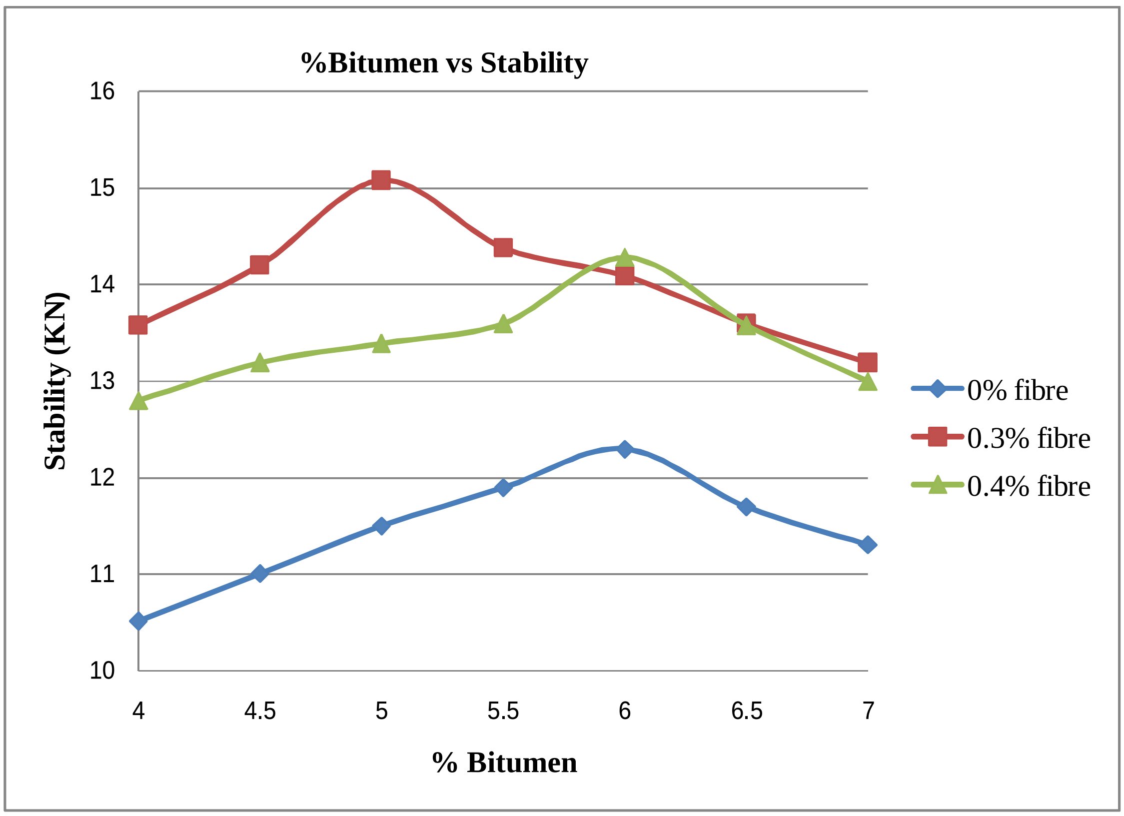

Fig 4.14 Variation of Stability Value of SMA with different binder content

(With different fibre content)

4.5.2 Flow value

It is observed that with increase binder content flow value increases. By addition of fibre 0.3% flow value decreases than o%, again further addition of fibre flow value increases.

For SMA flow value should be within 2 to 4 mm.. Variation of flow value with different binder content of SMA with different fibre content is show in fig 4.14

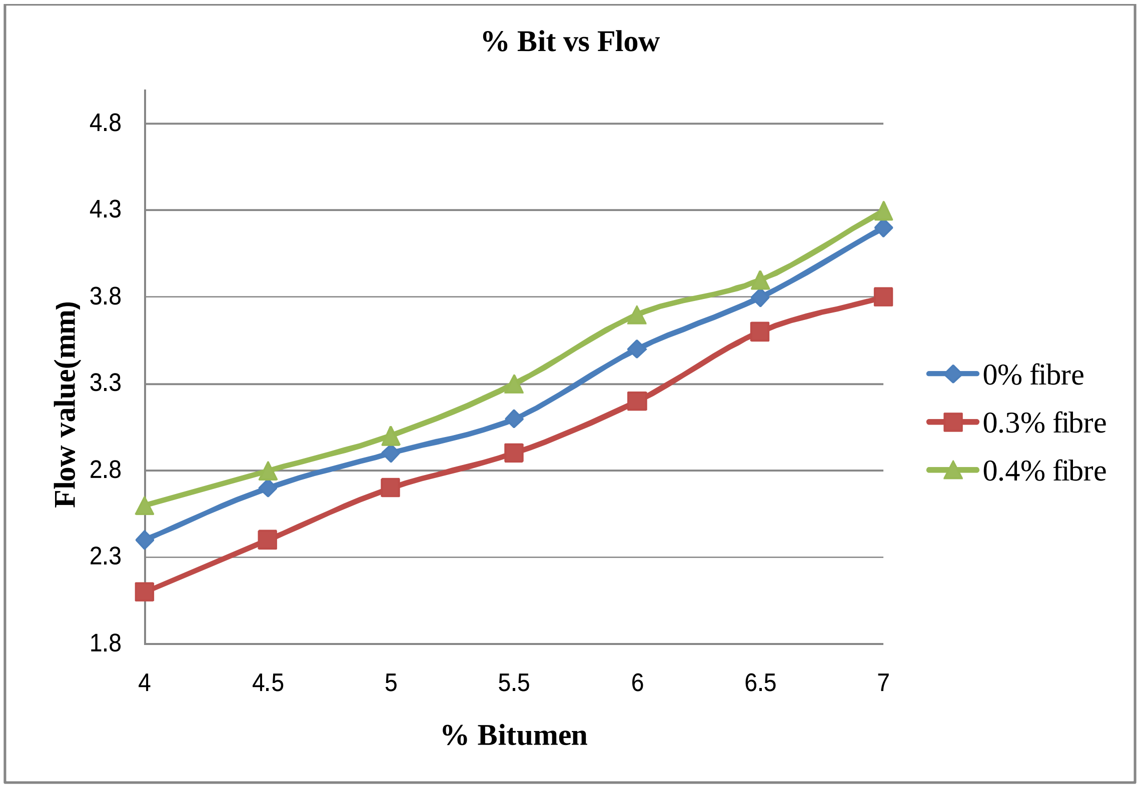

Fig 4.15 Variation of Flow Value of SMA with different binder content

(With different fibre content)

4.5.3 Unit Weight

It is observed that unit weight increases with increase binder content up to certain binder content; then decreases. Variation of unit weight value with different binder content with different fibre is given fig 4.15

Table 4.10 Maximum unit weight values and their corresponding binder content

Fibre content (%) >	0		0.3		0.4	
SMA with binder	Max. Unit wt.	Binder Content (%)	Max. Unit wt.	Binder Content (%)	Max. Unit wt.	Binder Content (%)
60/70	2.46	5	2.47	4.5	2.48	5

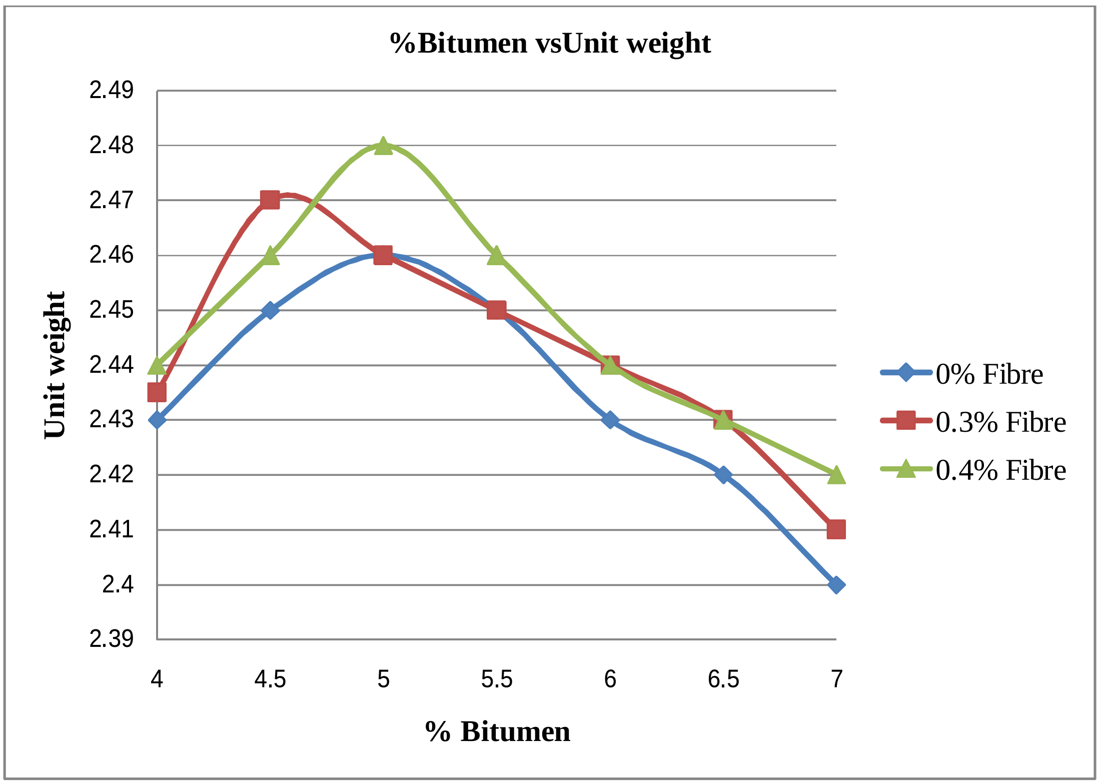

Fig 4.16 Variation of Unit Weight Value of SMA with different binder content

(With different fibre content)

4.5.4 Air Void

It is observed that with increase binder content air void decreases. Variation of air void content with different fibre content is given fig 4.16. MORTH recommended it should be lies between 2 to 4%. Hence the binder content at 3% of air void given below table 4.11

Table 4.11 binder content corresponding to 3% of air void

SMA with fibre content (%)	Air void (%)	Corresponding Binder Content (%)
0	3	6.5
0.3	3	6.5
0.5	3	7

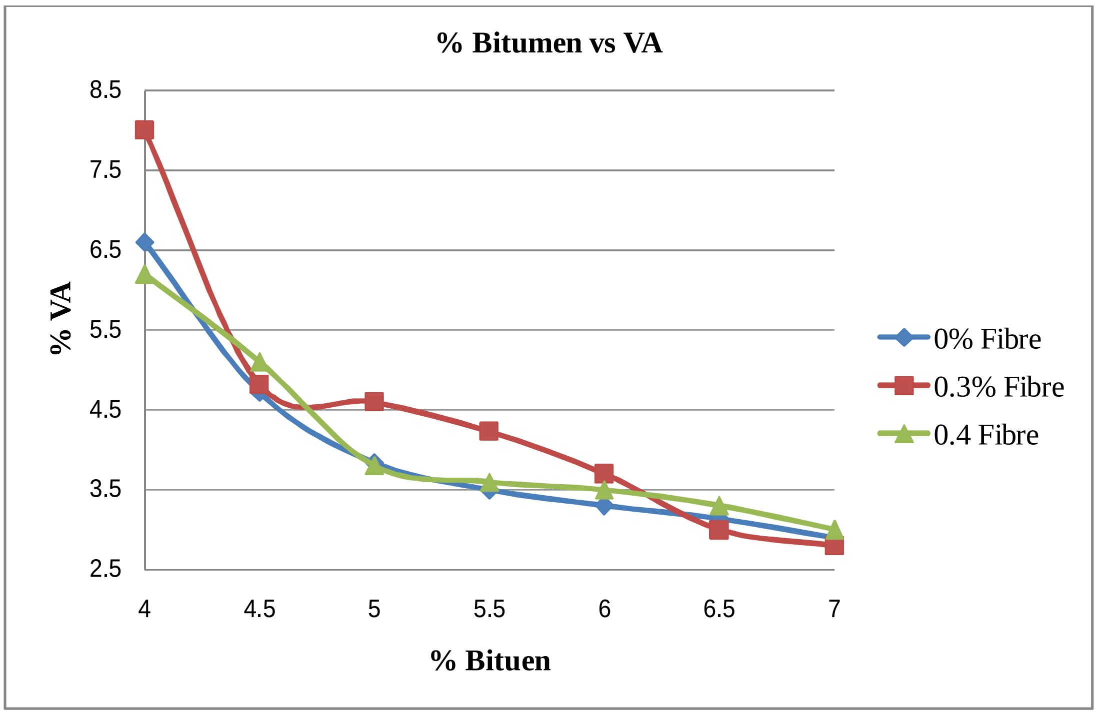

Fig 4.17 Variation of Unit Weight Value of SMA with different binder content

(With different fibre content)

4.5.5 Void In Mineral Aggregate (VMA)

It is observed that first it decreases and then it increases at sharp rate. Variation of VMA with different binder content with different fibre content is shown in Fig 4.17

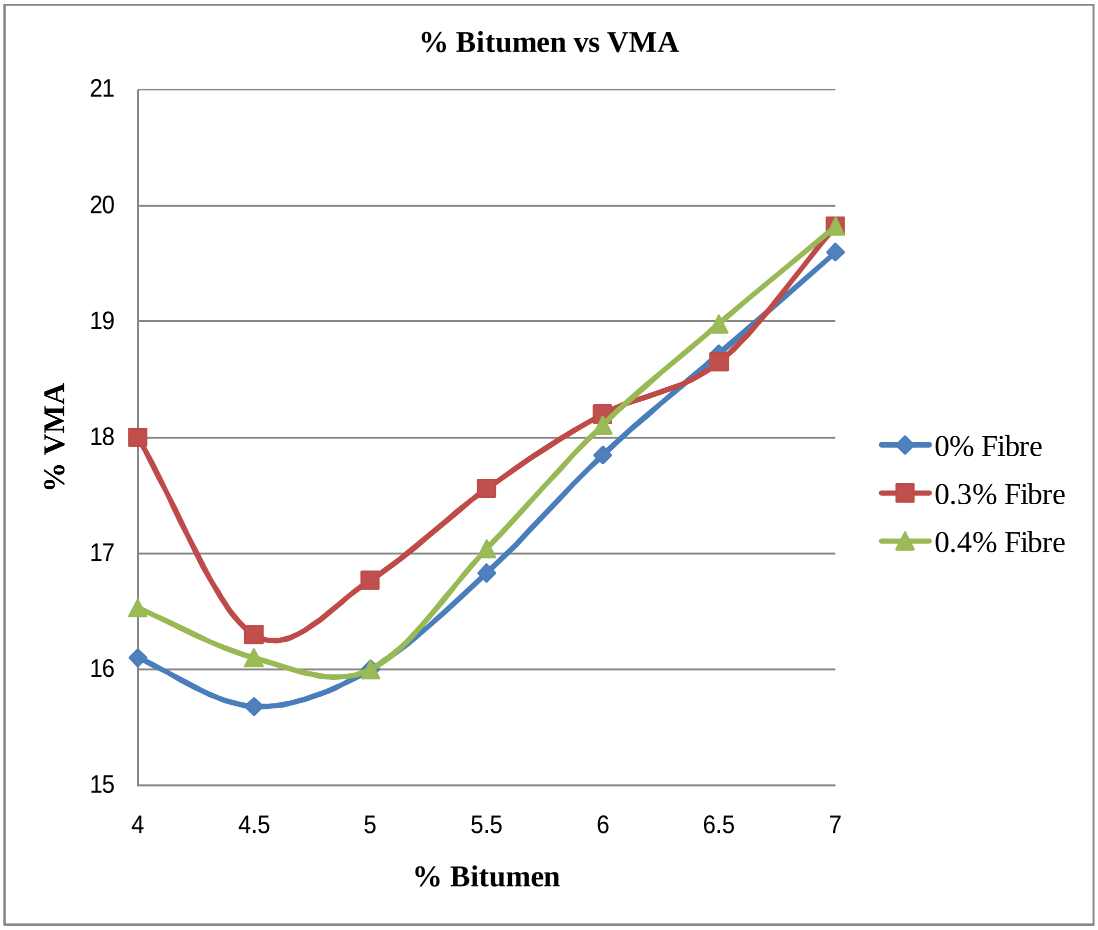

Fig 4.18 Variation of VMA Value of SMA with different binder content

(With different fibre content)

4.5.6 Void Filled With Bitumen (VFB)

It is observed that first it increases at sharp rate. Variation of VFB with different binder content with different fibre content is shown in Fig 4.18

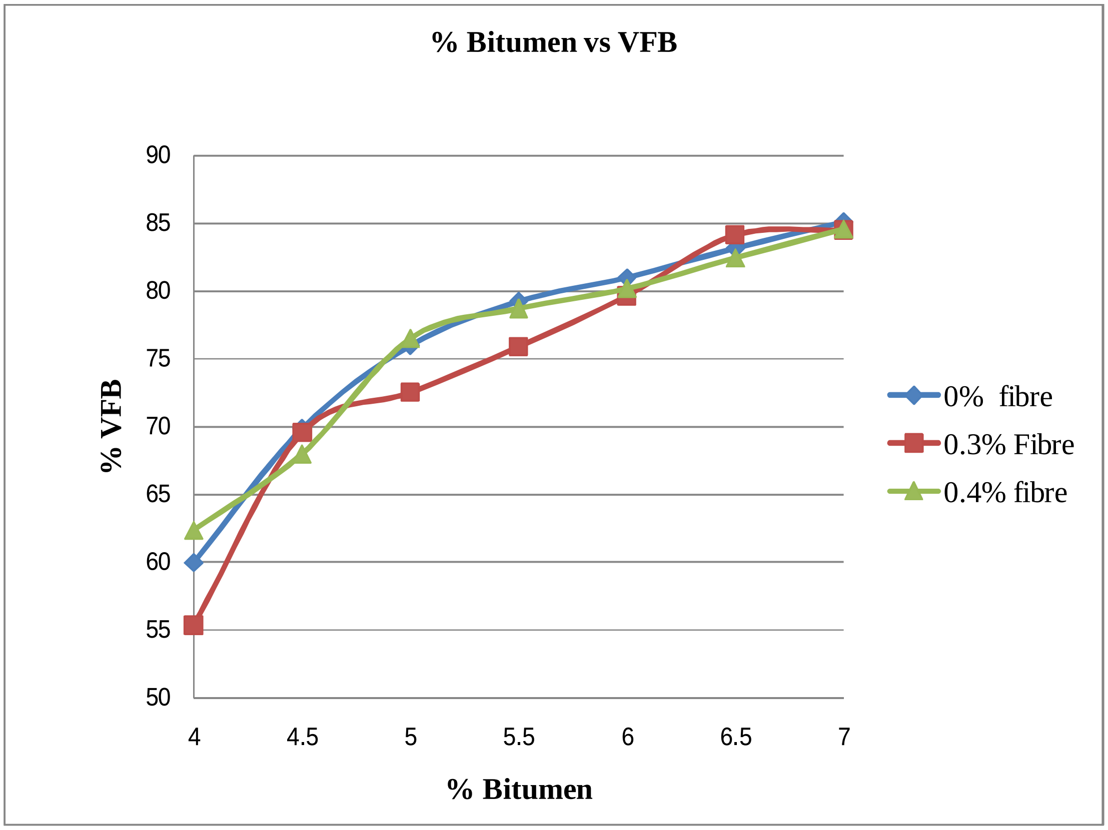

Fig 4.19 Variation of VFB Value of SMA with different binder content

(With different fibre content)

4.5.7 OPTIMUM BINDER CONTENT

Optimum Binder Content is found out by taking average value of following three bitumen content found from above graph i.e.

I. Bitumen content correspond to maximum stability
II. Bitumen content correspond to maximum unit weight
III. Bitumen content corresponding to the median of designed limits of percentage air voids in total mix

OBC of BC with different type of filler is given table 4.12

Table 4.12 OBC of SMA with different fibre content

BC With fibre content (%)	OBC (%)
0	5.8
0.3	5.2
0.4	6.2

Hence for SMA OBC is found as 5.2% and OFC is found as 0.3%. From above it is observed that by addition of 0.3% of fibre not only stability value increases but also binder quantity also decrease as compare to mixes contain 0.4% fibre. If binder content is more then it causes drain down of binder in mixes. Hence for SMA OFC is taken as 0.3%.

4.6 Drain down Characteristics

There the drain down characteristics of the SMA mixes prepared at their OBC and OFC were verified using the MORTH (2001) specifications as described in chapter 3. In this part, the results of the drain down tests are discussed.

4.6.1 Drain down of mixes without fibre

Table 4.5 gives the results of the drain down tests carried out on mixes without fibre and estimated by using Equation given in chapter 3. It can be observed from the results that SMA Mixes gives more drain down than BC because it contains more percentage of bitumen.

Table 4.13 Drain down of mixes without fibre

MIX	Drain down value (%)
SMA	0.08
BC	0.02

4.6.2 Drain down of mixes with fibre

It is observed that addition of the sisal fibre the drain down characteristics of mixtures decreases, Drin down value of SMA is reduced to 0.02% and there is no drain down of binder of BC.

4.7 Static Indirect Tensile Test

Static indirect tensile test of bituminous mixes measures the indirect tensile strength (ITS) of the mix which helps in assessing the resistance to thermal cracking of a given mix. The static indirect tensile tests were carried out on SMA and BC mixes prepared at their OBC and OFC as described in chapter 3. The effect of temperature on the ITS of mixes with and without fibre is also studied. The results of static indirect tensile test are presented and discussed in this section.

4.7.1 Effect of fibre on static indirect tensile strength

Figures 4.19 show the variations of indirect tensile strength with temperature for mixes. It is seen that the ITS value decreases with increase in temperature and for a particular binder, when fibre is added to the mix it increases.

4.7.2 Effect of temperature on static indirect tensile strength

Figures 4.19 show the variations of ITS value with temperature for mixes with and without fibre and with different binder content. It is observed that for a particular binder, the ITS value decreases with increase in temperature. At lower temperature, the SMA mixes has the highest indirect tensile strength than BC.

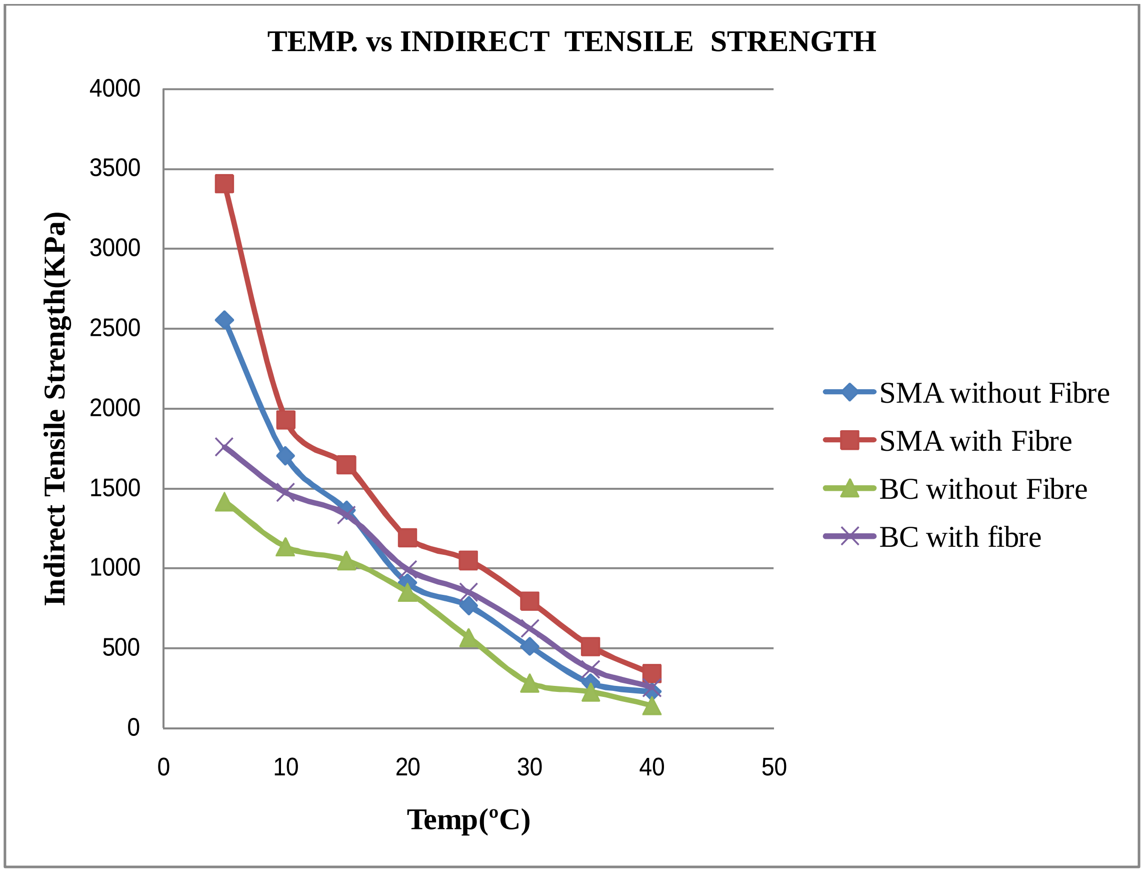

Fig 4.20 Variation of ITS Value of SMA and BC with different Temperatures

4.8 Static Creep Test

Static creep test is done to measure permanent deformation of bituminous mixes when static load is applied. It is observed from fig-20 that deformation of mix decreases by addition of fibre. If mix is prepared at their OBC and OFC and load is applied it has less deformation then mix without fibre. Another conclusion drawn is that deformation of BC is more than SMA.

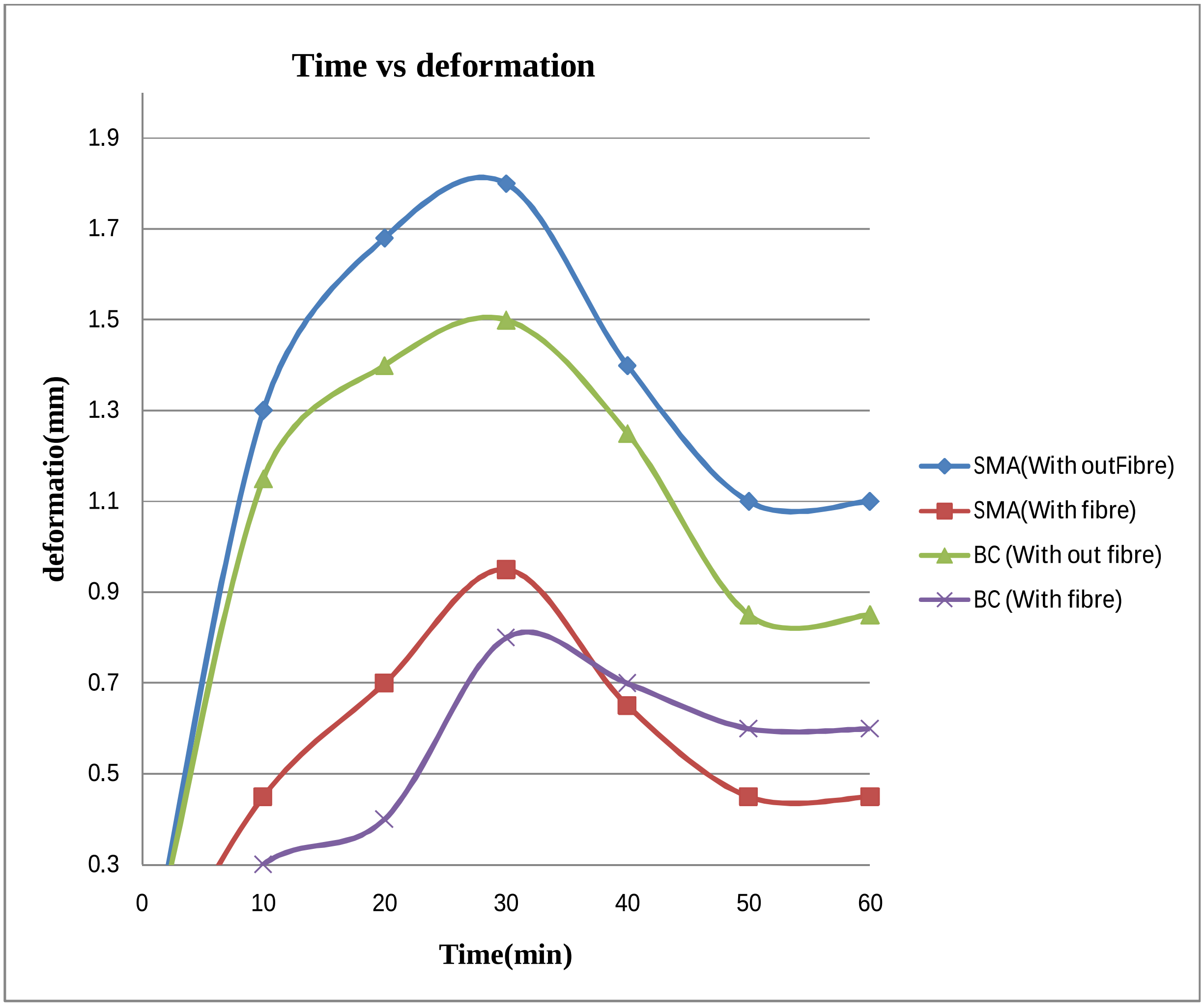

Fig 4.21 Deformation of SMA and BC (with and without fibre)

CHAPTER -5 **CONCLUSIONS**

5.1 General

Based on the results and discussion of experimental investigation carried out on mixes i.e. SMA and BC following conclusion are drawn.

5.2 BC with different type of filler

1) As per MORTH Specification mix design requirements of bituminous mix is given in table 5.1

Table 5.1 MORTH Specification mix design requirements of bituminous mix

Property	Value
Marshall stability (KN at 60°C)	>9KN
Flow Value (mm)	2-4
Air Void (%)	3-6
VFB (%)	65-75
OBC (%)	5-6

2) As BC made of from all the three type filler satisfy above requirements we can use them as filler.
3) Although BC with cement as filler gives maximum stability, as it is costly we can also use fly ash and stone dust as filler material.
4) Use of fly ash is helpful in minimise industrial waste.

5.3 BC With different Fibre content

1) Here OBC is 5%, OFC is found as 0.3%
2) By addition of fibre up to 0.3% Marshall Stability value increases and further addition of fibre it decreases. But addition of fibre stability value not increased as high as SMA.
3) By addition of fibre flow value also decreases as compare to mix without fibre, but addition of 0.5% fibre again flow value increases.

5.4 SMA With different Fibre content

1) Requirements of SMA according to IRC SP-79-2008 IS given in table 5.2

Table 5.2 IRCSP79-2008 Specification mix design requirements of SMA

Property	Value
Void (%)	4
Binder Requirement (%)	5.8 min
VMA (%)	17
OFC (%)	SHOULD NOT EXCEED 0.3%

Here OBC is 5.2% and OFC is 0.3%.

2) It is found that for SMA without fibre has binder requirement 5.8%, By addition of sisal fibre 0.3% to SMA this value is decreases to 5.2%. and further addition of fibre it increases up to 6 which leads to maximum drain down.
3) By addition of 0.3%fibre to SMA Stability value increases significantly and further addition to it, stability decreases.

4) By addition of 0.3%fibre to SMA flow value decreases and further addition of fibre flow value increases.
5) Main advantage of using fibre is that air void in mix decreases.
6) Drain down of binder decreases.

5.5 MIX at their OBC and OFC

Different test like Drain down test, Indirect Tensile Strength (ITS), Static creep test is done on MIX at their OBC, OFC and its conclusion is given below.

1) Drain down of SMA is more than BC without fibre. At their OFC drain down of binder is decreases.
2) From Indirect Tensile Strength it is concluded that Tensile Strength of SMA is more than BC.
3) From Static Creep Test it is concluded that by addition of fibre to BC and SMA mixes deformation reduced. MORTH recommended that permanent deformation should not be more than 0.5 mm. SMA sample with fibre shows deformation about 0.45mm which is good.

5.6 Concluding Remarks

Here two type of mix i.e. SMA and BC is prepared where 60/70 penetration grade bitumen is used as binder. Also a naturally available fibre called sisal fibre is used with varying concentration (0 to 0.5%). OBC and OFC is found out by Marshall Method of mix design. Generally by adding 0.3% of fibre properties of Mix is improved. From different test like Drain down test, Indirect Tensile Strength and static creep test it is concluded that SMA with using sisal fibre gives very good result and can be used in flexible pavement.

5.7 Future Scope

Many properties of SMA and BC mixes such as Marshall properties, drain down characteristics, tensile strength characteristics have been studied in this investigation. Only 60/70 penetration grade bitumen and a modified natural fibre called sisal fibre have been tried in this investigation. However, some of the properties such as fatigue properties, moisture susceptibility characteristics, resistance to rutting and dynamic creep behaviour can further be investigated. Some other synthetic and natural fibres and other type of binder can also be tried in mixes and compared. Sisal fibre used in this study is a low cost material, therefore a cost-benefit analysis can be made to know its effect on cost of construction. Moreover, to ensure the success of this new material, experimental stretches may be constructed and periodic performances monitored.

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